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DIVERGING PATHS TO ORGANIZATIONAL RESILIENCE: THE ROLE OF DYNAMIC MANAGERIAL CAPABILITIES, BENEVOLENT LEADERSHIP, ORGANIZATIONAL UNLEARNING AND PARADOXICAL THINKING

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Abstract: This paper investigates the determinants of organizational resilience, defined as the capacity to effectively counter and respond to external threats through organizational processes and strategic posture, and to recover from unexpected crises. It examines the role of dynamic managerial capabilities, leading to benevolent leadership, organizational ability to unlearn ineffective practices and processes, and handling strategic paradoxes, which collectively enable effective strategies for countering unexpected adversities. It argues that environmental dynamism (changeability) significantly influences the effectiveness of the aforementioned determinants of organizational resilience. Drawing on data collected from 379 Polish organizations between September and November 2023, the study tests these relationships using structural equation modeling (SEM). To further explore these complex relationships, fuzzy set qualitative comparative analysis (FsQCA) is employed to validate the SEM results. The findings indicate that dynamic managerial capabilities, coupled with benevolent leadership and organizational unlearning, contribute to increased organizational resilience, particularly in dynamic environments. However, paradoxical thinking has a minor inhibitory effect on organizational resilience. FsQCA analyses corroborate the SEM results but underscore the importance of deeper consideration of complexity in management studies.

Keywords: Organizational resilience, dynamic managerial capabilities, structural equation modeling, fuzzy set qualitative comparative analysis.

1. INTRODUCTION

Organizational resilience, often defined as an organization's capacity to effectively manage and overcome adversities (Weick, 1993, 2024), has garnered significant attention from both practitioners and scholars alike (Williams et al., 2021). The growing prevalence of external and internal challenges and disruptions has fueled interest in this concept (Danes et al., 2009; Williams & Shepherd, 2016; Clément & Rivera, 2017;). In this paper, organizational resilience is conceptualized following Duchek's (2020) framework, which views it as the organizational

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ability to anticipate potential threats, navigate unforeseen adversities effectively, and adapt to evolving conditions.

Irrespective of an organization's size or tenure, there's a concerted effort to cultivate capabilities geared towards weathering crises stemming from unpredictable environmental dynamics. While the manifestations of organizational resilience are observable during disruptions, there exists ongoing debate regarding the determinants of these critical organizational capabilities.

Organizational resilience may stem from various preconditions, yet researchers diverge in their conclusions regarding the organizational contexts that foster resilience. Consequently, this paper aims to address this research gap by examining how dynamic managerial capabilities, benevolent leadership, organizational unlearning, and paradoxical thinking, within the context of environmental dynamism, interact and influence organizational resilience.

To achieve this objective, data from 379 Polish organizations are analyzed using structural equation modeling (SEM). To ensure the robustness of the findings, SEM results are cross-validated with those obtained through fuzzy set qualitative comparative analysis. The ensuing discussion encompasses hypotheses derived from a literature review, methodological considerations, and implications, thus paving the way for future research directions.

2. LITERATURE REVIEW AND HYPOTHESES

2.1. Organizational resilience – the rise of interest

The concept of organizational resilience has surged in prominence in recent decades. Initially rooted in fields such as psychology and disaster management, the notion gradually permeated organizational studies, driven by a growing recognition of the need for businesses to navigate an increasingly complex and turbulent environment. One of the primary catalysts for the rise of organizational resilience is the frequency and severity of disruptions faced by businesses worldwide (Hillman & Guenther, 2021). These disruptions span a spectrum of sources, including natural disasters, economic downturns, geopolitical instability, technological advancements, and pandemics (Linnenluecke, 2017). The escalating interconnectedness of global economies and markets has amplified the ripple effects of such disruptions, underscoring the imperative for organizations to fortify their resilience.

Simultaneously, advances in technology and communication have accelerated the pace of change, fostering a dynamic and unpredictable operating environment (Vrontis et al., 2022). Organizations are confronted with rapid shifts in consumer preferences, market dynamics, regulatory frameworks, and competitive landscapes. In current conditions, the ability to anticipate, adapt, and recover from shocks is of a great importance (Andersson et al., 2019).

Scholars and practitioners have responded to these imperatives by delving deep into the topic, seeking to unveil its antecedents, manifestations, and implications (Duchek, 2020). This interest has spawned a rich body of literature, encompassing diverse disciplines such as management, strategy, psychology, or sociology (Hepfer & Lawrence, 2022). Researchers have developed frameworks, models, and tools to conceptualize, measure, and enhance organizational resilience, offering valuable insights to guide managerial practice (Chen et al., 2021).

In sum, the rise of the notion of organizational resilience reflects a fundamental shift in how organizations perceive and respond to uncertainty and adversity. It emphasizes the recognition that resilience is not merely a desirable trait but a strategic imperative for survival and success in today’s turbulent business landscape. However, the most important question remains, so far, unanswered. How does other organizational properties, strategies, and

processes enable organization to become resilient. This is the question about determinants of this important phenomenon.

2.2.On (numerous) determinants of organizational resilience

Pal et al. (2014) prepared a long list of organizational resilience enablers. In the paper, I focus on just a few of them – namely dynamic managerial competencies, as swift leaders manouver challenges effectively enabling the preparation of organization; leadership, which enables employees in making effective decision-making under pressure, organizational learning, as it creates the foundation for resilience to occur (Weick, 1993); and managing paradoxes by appropriate posture – while the increasing complexity requires effective balancing of competing tensions and contradictions (Hargrave & Van de Ven, 2017).

Firstly, dynamic managerial capabilities play a pivotal role in shaping organizational resilience by equipping leaders with the agility, foresight, and adaptability needed to navigate turbulent environments effectively (Helfat & Martin, 2015). These capabilities encompass a spectrum of competencies, including strategic visioning, decision-making agility, change leadership, and resource allocation acumen. Leaders adept in dynamic managerial capabilities exhibit a heightened capacity to anticipate emerging threats, seize opportunities, and mobilize organizational resources swiftly in response to changing circumstances. By fostering a culture of innovation, learning, and experimentation, these leaders cultivate organizational agility, enabling their teams to pivot rapidly in the face of disruptions. Moreover, dynamic managerial capabilities facilitate the alignment of organizational strategy with external realities, ensuring that businesses remain responsive and resilient amidst shifting market dynamics and competitive pressures (Huynh et al., 2022). In essence, by fostering a proactive and adaptive leadership ethos, dynamic managerial capabilities empower organizations to thrive in the landscape characterized by uncertainty and complexity. On this basis I formulate the first hypothesis:

H1: Dynamic managerial capabilities are positively linked organizational resilience.

Dynamic managerial capabilities are intertwined with leadership, and it may be argued, that benevolent leadership, as leaders with dynamic capabilities often demonstrate empathy, compassion, and a genuine concern for the well-being and development of their employees, fostering a supportive and nurturing work environment (Karakas & Sarigollu, 2012). This benevolent leadership style, coupled with dynamic managerial capabilities, fosters a culture of trust, collaboration, and psychological safety within the organization, which in turn enhances employee morale, engagement, and commitment. As a result, employees are more likely to demonstrate resilience in the face of adversity, proactively problem-solve, and adapt to changing circumstances, ultimately bolstering the overall resilience of the organization (Nonaka et al., 2016). This leads to the following two hypotheses:

H2: Benevolent leadership is positively linked to organizational resilience, and

H3: Benevolent leadership mediates the relationship between dynamic managerial capabilities and organizational resilience.

Further, dynamic managerial capabilities stimulate organizational unlearning, perceived as abandoning ineffective practices, routines and processes to create a space for new solutions (Tsang & Zahra, 2008), by encouraging a culture of openness to new perspectives, experimentation, and reflection, which prompts individuals and teams to challenge existing assumptions, routines, and mental models. This process of organizational unlearning facilitated by dynamic managerial capabilities enables the organization to shed obsolete practices, beliefs, and strategies, thereby enhancing its ability to adapt to evolving conditions and respond

effectively to disruptions, ultimately strengthening its resilience in the face of uncertainty and change. This leads to the following two hypotheses:

H4: Organizational unlearning is positively linked to organizational resilience, and

H5: Organizational unlearning mediates the relationship between dynamic managerial capabilities and organizational resilience.

Finally, managers encompassing dynamic managerial competencies are able to encourage employees to think differently – look at the problem from different perspectives. Paradoxical thinking, understood as ability to perceive the reality from different standpoints, balancing contradictive tensions, enable organization to become more resilient in the face of crisis (Förster et al., 2022). This leads to the next two hypotheses:

H6: Paradoxical thinking is positively linked to organizational resilience, and

H7: Paradoxical thinking mediates the relationship between dynamic managerial capabilities and organizational resilience.

Finally, organizations do not operate in a vacuum. Since the dynamism of the environment pose significant challenges on the everyday's life, it may be assumed that the dynamism of the environment effectively changes – moderates – the effectiveness of organizational endeavours, and affects the company handles adversities and crises (Do et al., 2022). This enables formulation of a final hypothesis:

H8: Environmental dynamism moderates relationships between benevolent leadership, organizational unlearning, paradoxical thinking and organizational resilience.

3. METHODOLOGY

3.1. Sample characteristics

To test the research hypotheses, I employed a quantitative research approach based on empirical data gathered from companies' representatives. In the first step, a questionnaire reflecting the tested variables was created (the research model was operationalized), which was later distributed to a random sample of 1000 companies selected from a database containing 10,009 entries in September 2023. Simultaneously, a second sample of the same size was randomly selected from the database. Questionnaires were sent to the representatives of the first sample. If the selected company from the first sample did not agree to participate in the study, the questionnaire was then sent to a company from the second sample marked with the same number. In this manner, 402 questionnaires were gathered, from which 379 were included in the final sample. Questionnaires with missing data or assessed as non-reliable (for example, containing the same answers for all the questions) were removed from the sample. This yielded a rather unimpressive effective response rate of nearly 20%, which is consistent with other studies.

In the sample, there were 72 trading, 193 service, 35 production, and 79 mixed-type companies. 100 respondents declared that their companies operate locally, 71 had regional reach, 130 were reaching customers nationally (in Poland), and there were also 63 international and 15 global companies. The median size of the studied organizations equaled 14, with a mean equal to 241 and a standard deviation of 1155. The smallest company employed just 2 people, while the largest employed more than 17,000, indicating a highly skewed sample (skewness = 10.069) and kurtosis equaled 129, signifying that the distribution of the data is non-normal.

Considering the age of organizations, the median equaled 16 with a mean equal to 19.91 years, and a standard deviation of 18.3. Skewness equaled 3.81 with kurtosis of 23.93. 178 companies were family-owned, and 201 were non-family businesses.

3.2. Measures

The main dependent variable, organizational resilience, was measured using the questionnaire proposed by Orth and Schuldis (2021), composed of 8 items measured on a 7-point Likert scale. Cronbach's alpha for the scale equaled 0.873. Exploratory factor analysis (KMO = 0.880, Bartlett's test: chi-square = 1351.35 with 28 degrees of freedom, $p < 0.001$) revealed that organizational resilience is a unidimensional construct, and one factor explains roughly 54% of the variance of all the items.

Dynamic managerial capabilities were measured using a 6-item research tool measured on a 7-point Likert scale, previously developed and tested by Schilke (2014). Cronbach's alpha equaled 0.837, but one item reflecting the diversification of staff in a company was removed after the analysis. Its removal improved the value of alpha to a more respectable level of 0.876. Exploratory factor analysis (KMO = 0.849, Bartlett's test: chi-square = 937.86, with 10 degrees of freedom, and $p < 0.001$) revealed that one factor explains over 67% of the items' variance.

Benevolent leadership was operationalized following the framework proposed by Cheng et al. (2004). The scale, comprising 11 items, demonstrated high internal consistency (Cronbach's alpha = 0.946) and constituted a unidimensional construct (KMO = 0.940; approx. chi-square = 3453.235 with 55 degrees of freedom, $p < 0.001$), explaining over 66% of the cumulative variance of the items.

Organizational unlearning was measured using the scale developed by Lyu et al. (2020), composed of 6 items measured on a 7-point Likert scale. Cronbach's alpha for the scale accounted for 0.899, signifying high reliability of the construct. Exploratory factor analysis (KMO = 0.865, Bartlett's test: chi-square = 1368, with 15 degrees of freedom, $p < 0.001$) showed that organizational unlearning is a unidimensional construct, and one factor explains over 66.5% of the variance of all the items.

Paradoxes were measured using the scale previously created by Ingram et al. (2016), composed of 6 items measured on a 7-point Likert scale. Cronbach's alpha for the scale was not satisfactory, equalling 0.642. However, after removing the first item, the value of the coefficient increased to 0.685 – still below the 0.7 cut-off line, but such values can be cautiously included in the research. Exploratory factor analysis for the scale revealed it is a unidimensional construct, with one factor explaining 45% of the cumulative variance.

Finally, environmental dynamism was measured using a 5-item long scale developed and tested by Kwiotkowska (2018). Cronbach's alpha for the scale equaled 0.780, and exploratory factor analysis revealed that a single construct explains nearly 54% of the cumulative variance of all the items (KMO = 0.747, Bartlett's test: chi-square = 540.68, with 10 degrees of freedom, p-value < 0.001).

4. RESEARCH RESULTS

The initial phase of the analysis involved examining a model consisting of six components: organizational resilience as the dependent variable, dynamic managerial capabilities as the primary independent variable, and paradoxical thinking, organizational unlearning, and benevolent leadership as mediators, with environmental dynamism serving as a moderator. This phase aimed to investigate correlations between the variables. Spearman's rank correlation coefficients, along with descriptive statistics, were calculated for this purpose. Metavariables were computed as the mean of all the items comprising the variable. The findings are summarized in Table 1.

Table 1. Spearman's rank correlations and descriptives

	1	2	3	4	5	6	7	8
1. Organizational resilience	1,000							
2. Dynamic managerial capabilities	,594**	1,000						
3. Benevolent leadership	,589**	,343**	1,000					
4. Organizational unlearning	,696**	,469**	,490**	1,000				
5. Paradoxical thinking	-,073	-,098*	-,024	-,079	1,000			
6. Environmental dynamism	,418**	,183**	,308**	,274**	,108*	1,000		
7. Log size	-,207**	-,006	-,335**	-,107*	,043	-,184**	1,000	
8. Log age	-,107*	-,097*	-,195**	-,127**	,015	-,115*	,521**	1,000
Mean	5,18	4,94	4,70	5,07	3,14	4,88	1,25	1,17
Sd	0,90	0,90	1,21	1,04	0,63	0,97	0,82	0,35

** - correlation significant at p<0.01, single-tailed; * - correlation significant at p<0.05, single-tailed, n=379.

Spearman's rank correlations were chosen due to the non-normal distribution of the studied variables, and single-tailed p-values were used for calculating correlations. Examining the correlation table reveals relatively high relationships between organizational resilience and dynamic managerial capabilities ($\rho = 0.594$, $p < 0.01$), benevolent leadership ($\rho = 0.589$, $p < 0.01$), organizational unlearning ($\rho = 0.696$, $p < 0.01$), and environmental dynamism ($\rho = 0.418$, $p < 0.01$). Conversely, the correlation between organizational resilience and paradoxical thinking was insignificant ($\rho = -0.073$).

Dynamic managerial capabilities significantly correlate with benevolent leadership ($\rho = 0.343$, $p < 0.01$), organizational unlearning ($\rho = 0.469$, $p < 0.01$), and environmental dynamism to a lesser extent ($\rho = 0.183$, $p < 0.01$). The correlation with paradoxical thinking is significant, albeit with a negative sign ($\rho = -0.089$, $p < 0.05$).

Benevolent leadership exhibits a strong correlation with organizational unlearning ($\rho = 0.490$, $p < 0.01$) and a significant correlation with environmental dynamism ($\rho = 0.308$, $p < 0.01$). However, it does not significantly correlate with paradoxical thinking.

Organizational unlearning does not significantly correlate with paradoxical thinking, but it does correlate with environmental dynamism ($\rho = 0.274$, $p < 0.01$). Conversely, paradoxical thinking demonstrates negative correlations with all variables except for its relationship with environmental dynamism ($\rho = 0.108$, $p < 0.05$), albeit relatively small.

Table 2. Linear regression coefficients and multicollinearity statistics

Model	Unstandardized parameters	Standard error	Standardized parameters (Beta)	t-value	p-value	Multicollinearity statistics	
						Tolerance	VIF
Constant	0,389	0,229	1,696	0,091	-	-	-
Benevolent leadership	0,183	0,026	0,246	6,988	<,001	0,693	1,442
Organizational unlearning	0,34	0,032	0,394	10,802	<,001	0,646	1,547
Dynamic capabilities	0,29	0,034	0,288	8,51	<,001	0,75	1,333
Paradoxical thinking	-0,031	0,042	-0,022	-0,725	0,469	0,974	1,027
Environmental dynamism	0,178	0,029	0,191	6,109	<,001	0,875	1,142
Dependent variable: organizational resilience							

The size and age of organizations generally exhibit weak to moderate correlations with other variables, typically negative, indicating that older and larger organizations tend to have lower levels of other variables. These two variables covary significantly in the model ($\rho = 0.521$, $p < 0.01$). The relatively high correlation levels may indicate autocorrelation issues in further analyses. To address this concern, a VIF analysis was conducted in the next step. Initially, regression analyses with VIF statistics were calculated, with organizational resilience as the main dependent variable and all other variables as independent ones. Control variables were omitted in this analysis. Table 2 presents the results of the VIF analysis (and parameter estimates).

As indicated in Table 2, VIF statistics do not exceed 4, which is commonly perceived as an indicator of multicollinearity between variables. Additionally, the coefficients in the table exhibit the same direction (the same sign) as the relationships indicated in the correlation matrix, suggesting that the probability of multicollinearity is low.

Therefore, in the subsequent steps, I conducted structural equation modeling using Mplus software. Initially, following the recommendations of Boemelburg et al. (2023), I assessed the internal consistency of the model using confirmatory factor analysis. At this stage, I specified the internal structure of latent variables (all variables in the model were treated as latent ones). The estimation results are presented in Figure 1.

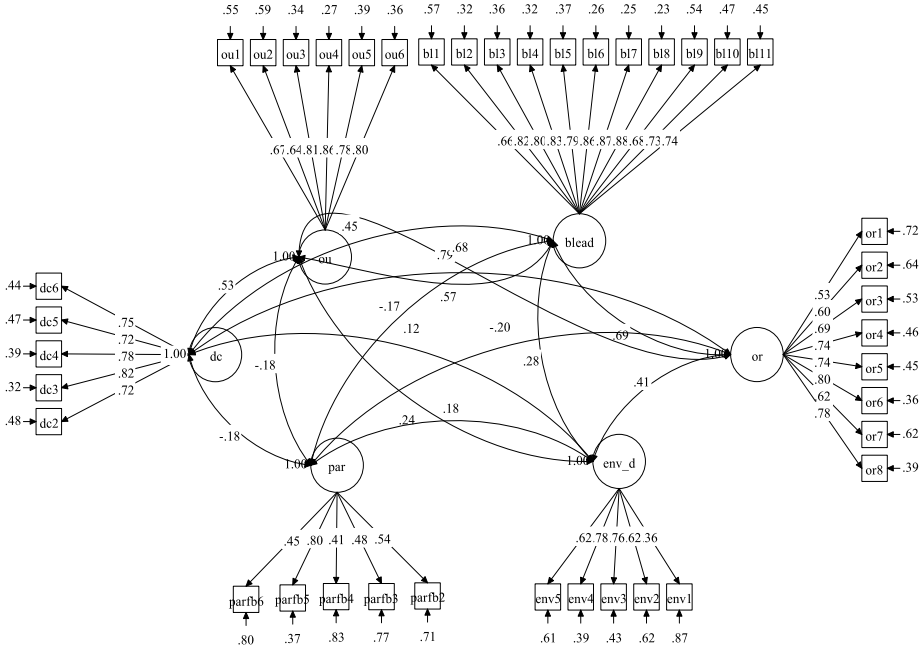

Figure 1. Confirmatory factor analysis: The measurement model

Legend: dk – dynamic capabilities, ou – organizational unlearning, par – paradoxical thinking, blead – benevolent leadership, or – organizational resilience, env_d – environmental dynamism. Above the lines factor loadings are provided. Latent variables covary, and covariances are given above the lines.

As illustrated in the model presented in Figure 1, most of the factor loadings are statistically significant. Moreover, the model demonstrates a reasonable fit with RMSEA = 0.046, CFI = 0.922, TLI = 0.914, SRMR = 0.066, and Akaike AIC = 42,610.266. These results suggest that the proposed structure aligns well with the data and supports further analyses. However, due to poor factor loadings, item "env1" with a value of 0.36 was excluded from subsequent analyses.

In the following step, a structural equation model was estimated using a random type of analysis with MLR estimator and integration algorithm, allowing for testing of the mediation and moderation effects between latent variables. In this type of analysis, no fit indices are provided, and thus, the model's quality is evaluated using comparative measures, such as Akaike AIC, compared to the base model. Lower AIC levels indicate a better fit, while significantly higher AIC levels suggest a poor fit of the model to the data. To enhance clarity, a graphical representation of the model was created using the draw.io web application. The estimation results are presented in Figure 2.

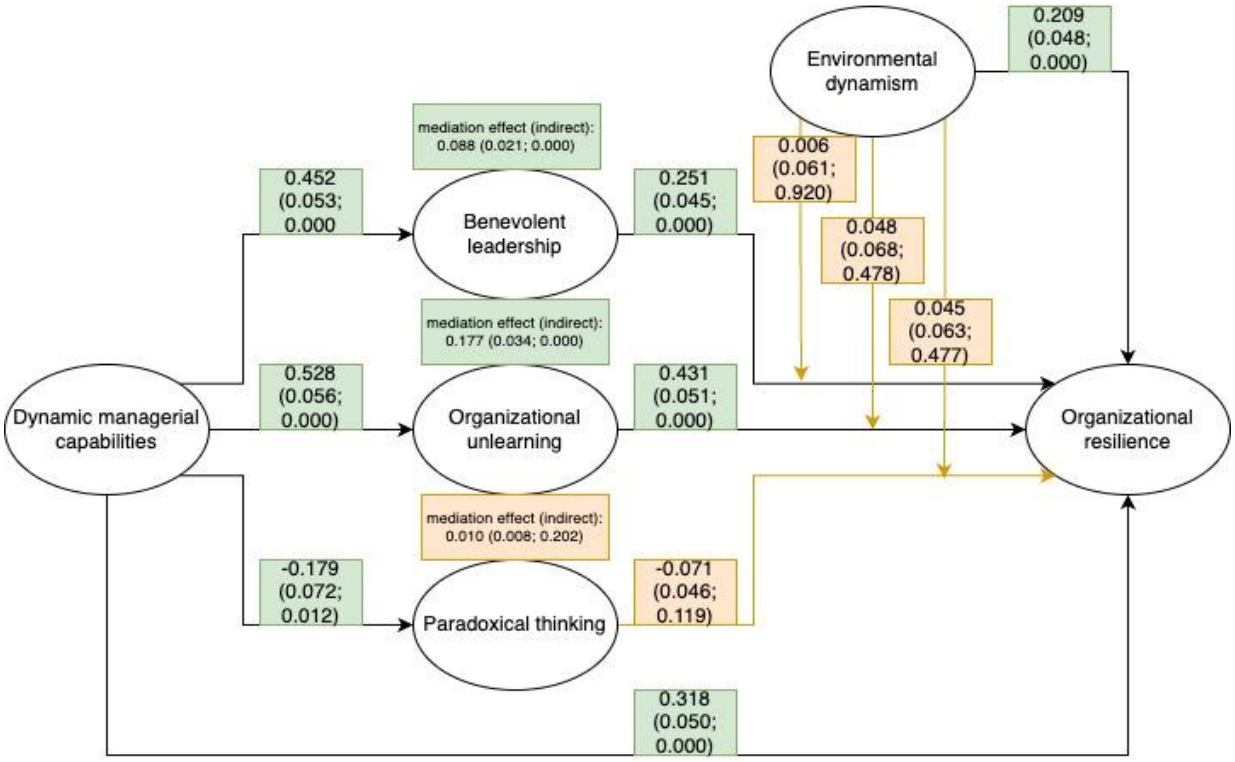

Figure 2. Structural model of relationships between dynamic managerial capabilities and organizational resilience with mediation effect of benevolent leadership, organizational unlearning, and paradoxical thinking and moderating effect of environmental dynamism

Legend: Above lines standardized parameters, standard errors and p-values are provided. Green color denotes significant relationships, orange color – relationships statistically insignificant. For a better clarity structural loadings are removed.

The model presented in Figure 2 exhibited relatively good fit, with Akaike AIC = 42,653.522. In comparison with the Akaike of the structural model presented in Figure 1, it is slightly less well-fitted, with the change accounting for 41 points.

To summarize the analyses, as depicted in Figure 2, dynamic managerial capabilities foster organizational resilience both directly (standardized coefficient = 0.318) and indirectly, through benevolent leadership (mediation effect of 0.088) and organizational unlearning (mediation effect = 0.177). Dynamic managerial capabilities significantly influence all three mediating variables, most prominently benevolent leadership (standardized coefficient = 0.452) and organizational unlearning (standardized coefficient = 0.528), while also exerting a negative influence on paradoxical thinking (standardized coefficient = -0.179).

Both benevolent leadership (standardized coefficient = 0.251) and organizational unlearning (standardized coefficient = 0.431) significantly influence organizational resilience, whereas paradoxical thinking shows no significant relationship with organizational resilience (standardized coefficient = -0.071).

In the estimated model, environmental dynamism does not significantly moderate the relationships between benevolent leadership, organizational unlearning, paradoxical thinking, and organizational resilience. However, it does strengthen the level of organizational resilience (standardized coefficient = 0.209).

5. ROBUSTNESS CHECKS

To ensure the robustness of the results, I chose to specify the model differently. Embracing a configurational approach to management, I posited that various configurations of dynamic managerial capabilities, organizational unlearning, benevolent leadership, paradoxical thinking, and environmental dynamism could lead to increased organizational resilience. From this configurational perspective, I hypothesized that different combinations of determinants might foster the development of organizational resilience capability within the organization. Configurational approaches in management studies are predicated on causal asymmetry, where a particular outcome may result from specific conditions, and the absence of the outcome may stem from a very different set of conditions. Hence, I opted to utilize fsQCA (see Fiss, 2011) to test this assumption. Accordingly, I employed fuzzy set qualitative comparative analysis to identify configurations of factors associated with both increased and decreased organizational resilience. In conducting the analyses, I adhered to the recommendations of Pappas & Woodside (2021).

In the initial step, the data (metavariables used to calculate correlations) were transformed into fuzzy sets using a calibration method with values ranging from – to 1. Statistics utilized for data calibration are provided in Table 3.

Table 3. Statistics used to compute thresholds

Variable	Benevolent leadership	Organizational unlearning	Organizational resilience	Dynamic managerial capabilities	Environmental dynamism	Paradoxical thinking
5th percentyle	2,545	3,333	3,75	3,333	3,2	2
50th percentile (median)	4,72	4,9	5,12	4,9	4,7	3,1
95th percentile	6,636	6,833	6,625	6,333	6,4	4,166

Calibration measures play a crucial role in assessing the goodness of model fit. Thanks to the calibration procedure, I was able to harmonize data collected across different Likert scales. All computations were conducted using dedicated software – FSQCA, available from https://sites.socsci.uci.edu/~cragin/fsQCA/software.shtml.

Additionally, I conducted a truth table analysis with a frequency cutoff set at 5. This approach resulted in the removal of approximately 5 percent of all observations, eliminating configurations that were rarely present from the analysis. The outcomes of the analysis encompass complex, parsimonious, and intermediate combinations of configurations.

A complex solution represents a comprehensive set of conditions leading to a specific outcome. However, these conditions are sufficient but not necessary for the outcome to occur. Consequently, researchers typically focus on two other solutions provided by the program.

The parsimonious solution comprises combinations of conditions that are deemed necessary for a particular outcome to manifest and is part of the intermediate solution, which is commonly regarded as the most relevant set of significant conditions for the outcome to occur. Typically, results are presented with intermediate solutions, clearly indicating (often highlighted) the parsimonious components contained within. The parsimonious and

intermediate solutions for both high and low levels of organizational resilience are detailed in Tables 4 and 5, respectively.

Table 4. Intermediate configurations leading to high organizational resilience

	Intermediate solution (with parsimonious solution highlighted)	raw coverage	unique coverage	consistency
1	**BLead * OUnlearn**	0.70845	0.0552464	0.885788
2	**OUnlearn * DynCap**	0.715293	0.0669392	0.894173
3	**OUnlearn * ~ParTh * Env_D**	0.468215	0.0095479	0.909091
4	**DynCap** * ~ParTh * **Env_D**	0.449477	0.0077610	0.893797
5	Blead * **DynCap** * **Env_D**	0.556497	0.0199131	0.907494
Consistency cutoff: 0.867622				
solution coverage: 0.88241				
solution consistency: 0.8293				

Blead – benevolent leadership, OUnlearn – organizational unlearning, DynCap – dynamic managerial capabilities, ParTh – paradoxical thinking, Env_D – environmental dynamism; "~" stands for a low level of a condition; lack of "~" signifies high level of a condition for an outcome to occur.

Table 5. Intermediate configurations leading to low organizational resilience

	Intermediate solution (with parsimonious solution highlighted)	raw coverage	unique coverage	consistency
1	**~BLEAD*~DC***~PARTH	0.442205	0.0100461	0.913593
2	**~BLEAD*~OU***~PARTH	0.453944	0.0093365	0.921628
3	**~BLEAD*~DC***ENV_D	0.461206	0.0132677	0.902457
4	**~BLEAD***DC***PARTH*~ENV_D**	0.341796	0.0096093	0.913069
5	**~OU*~DC***PARTH*ENV_D	0.415724	0.0340157	0.937108
6	**~BLEAD*~OU***~ENV_D	0.555282	0.0045318	0.944992
7	~BLEAD***~OU*~DC**	0.597925	0.0216761	0.952095
Consistency cutoff: 0.89993				
solution coverage: 0.752661				
solution consistency: 0.870705				

Blead – benevolent leadership, OUnlearn – organizational unlearning, DynCap – dynamic managerial capabilities, ParTh – paradoxical thinking, Env_D – environmental dynamism; "~" stands for a low level of a condition; lack of "~" signifies high level of a condition for an outcome to occur.

Solution coverage, defined as the extent to which identified solutions account for the observed cases of the outcome, is relatively high, indicating that the identified combinations of conditions explain a significant portion of the observed cases. Specifically, it stands at 88% and 75%, respectively. Conversely, consistency, referring to holding consistency across different cases in the dataset, is also high, at 0.82 and 0.87, respectively. This signifies that the results are consistent and explain a majority of the cases studied.

As depicted in Table 4, there are five configurations leading to high organizational resilience within a company. In this solution, both organizational unlearning and dynamic managerial capabilities, along with benevolent leadership and high dynamism of the environment, contribute to the creation of increased organizational resilience. Additionally, firms should adopt a relatively straightforward approach to dilemmas and contradictions. However, paradoxical thinking negatively influences organizational resilience in two out of the five configurations. Conversely, in one configuration, such a streamlined approach to embedded complexity pays dividends in terms of creating organizational resilience capabilities.

Table 5, on the other hand, illustrates that low levels of organizational resilience result from seven configurations. In the majority of cases, low levels of benevolent leadership, organizational unlearning, and dynamic managerial capabilities are critical factors leading to

decreased levels of organizational resilience. Only in one solution does a low level of environmental dynamism, signifying favorable environmental conditions, also appear to contribute to low levels of organizational resilience.

6. DISCUSSION AND CONCLUSIONS

The primary objective of this study was to underscore the pivotal role of dynamic managerial capabilities, coupled with organizational unlearning, benevolent leadership, and paradoxical thinking, in fostering organizational resilience in highly dynamic environments. Out of the 8 research hypotheses, there is clear support for the claim that dynamic managerial capabilities create conditions in which organizational resilience may emerge. This supports H1. Next, benevolent leadership facilitates the emergence of organizational resilience and partially mediates the relationships between dynamic managerial capabilities and organizational resilience. This supports the second hypothesis and partially supports the third, while the effect should be described as partial mediation. Thirdly, SEM analyses confirm that organizational unlearning is positively linked to organizational resilience, confirming the fourth hypothesis. The fifth hypothesis can be partially supported, while there is a partial mediation effect of organizational unlearning in the relationship between dynamic managerial capabilities and organizational resilience. Fourthly, paradoxical thinking is not significantly linked to organizational resilience, which falsifies the sixth hypothesis. It does not mediate the relationship between dynamic managerial capabilities and organizational performance as well, signifying rejection of the seventh hypothesis. Finally, environmental dynamism does not effectively moderate relationships between mediators and organizational resilience, which falsifies the eighth hypothesis.

The integration of findings from structural equation modeling (SEM) and fuzzy-set qualitative comparative analysis (fsQCA) yields insightful observations. Notably, within highly dynamic contexts, the cultivation of dynamic managerial capabilities, benevolent leadership, and organizational unlearning appears conducive to bolstering organizational resilience. Conversely, an abundance of paradoxical thinking appears to impede organizational efforts towards heightened resilience. However, the intricacies revealed by fsQCA suggest a nuanced reality—there exist numerous alternative pathways through which organizational resilience may be attained. Moreover, the absence or low presence of a specific condition or independent variable does not necessarily equate to diminished organizational preparedness or recovery capabilities in the face of adversity. This underscores the value of a configurational approach to studying organizational phenomena, shedding light on the inherent complexity of modern organizations (Kumar et al., 2022). Consequently, organizational strategies predicated on assumptions of universal best practices may fall short in addressing real-world complexities, underscoring the need for more adaptive and context-sensitive approaches (Meyer et al., 1993).

The study clearly demonstrates how organizational resilience might be achieved through diverse pathways. While certain antecedents help bolster the level of organizational preparedness for adversity (such as dynamic managerial capabilities, benevolent leadership, and organizational unlearning), they might become ineffective in certain configurations of other factors. Thus, for a better understanding of organizational resilience, it can be argued that more in-depth qualitative studies might be necessary to comprehend the role of certain conditions in facilitating organizational resilience. For example, benevolent leadership might be effective in specific conditions, which may not hold true if the conditions change (Papworth et al., 2009).

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ICT PENETRATION AND STOCK MARKET DEVELOPMENT: EMPIRICAL EVIDENCE FROM EMERGING MARKET ECONOMIES

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Abstract: Stock markets play a vital role for economic growth and development through providing capital to businesses and investment options to the investors. Therefore, determination of factors underlying stock market development is significant to make the economic progress. This study investigates the interaction between ICT indicators including internet usage, mobile cellular subscriptions, and fixed broadband subscriptions and stock market development in the emerging market economies over the 2001-2022 period through causality analysis. The results of the panel level causality analysis uncover a mutual interaction between ICT indicators and stock market development. However, the results of the cross-sectional causality analysis reveal that the interaction between ICT indicators and stock market development differs among the emerging market economies.

Keywords: ICT indicators, stock market development, emerging market economies, panel causality test.

1. INTRODUCTION

Stock markets have become one of the drivers of economic growth and development through the channels of liquidity creation, savings mobilization, risk diversification, acquisition and dissemination of information about firms, and corporate governance (Demirgüç-Kunt & Levine, 1996; Dike, 2016). However, stock market liquidity can also negatively impact economic growth by decreasing savings rate through income and substitution effects (Devereux & Smith, 1994). Furthermore, risk diversification can also negatively impact economic growth through decreasing savings rates (Devereux & Smith, 1994; Levine, 2004). However, the majority of empirical studies have uncovered a positive impact of various stock market indicators on economic growth and development for different countries and country groups (Bui & Doan, 2021; Kapaya, 2020; Chikwira & Mohammed, 2023).

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The critical role of stock markets for the economies has motivated the researchers to conduct the factors underlying stock market development. The studies have uncovered that economic factors including as income level, gross domestic investment, banking sector development, private capital flows, stock market liquidity, trade and financial openness and institutional factors including different legal origins, stock market integration, legal protection of investors, and corporate governance are significant determinants of stock market development (Garcia & Liu, 1999; Yartey, 2008; Ho & Iyke, 2017; Adjasi et al., 2022).

ICT can also impact stock market development through introducing electronic markets and automatic order execution which result in lower fees, more efficient markets, and greater information and transparency for investors (Lee et al., 2019). However, spread of false information about stocks through ICT can negatively affect stock market development (Lee et al., 2019). On the other hand, stock market development can positively impact ICT penetration through increasing the use of ICT at the society. In conclusion, a bilateral causal interplay between ICT indicators and stock market development is theoretically expected.

In this study, we investigate the ICT indicators on stock market development in the emerging markets considering the gap in the empirical literature, although the globalized world has achieved significant progress in ICT penetration. Furthermore, the studies have generally investigated the effect of ICT indicators on stock market development. The bilateral interplay between ICT indicators and stock market development is examined unlike the related empirical literature. In the rest of the paper, Section 2 reviews the empirical literature on the nexus between ICT and stock market development. Section 3 defines the dataset and methodology and Section 4 performs the econometric tests and discusses the results of the causality analysis. The paper is concluded with the Conclusions.

2. LITERATURE REVIEW

Stock markets have remarkably developed with the contribution of the globalization process during the past four decades. Therefore, economic impacts of stock markets and drivers of stock market development have been widely explored. In this study, we focus on the bilateral interplay between ICT indicators and stock market development considering the gap in the empirical literature. In the related empirical literature, Lee et al. (2017), Afshan et al. (2020), Igwilo and Sibindi (2022), and Suragan and Durmuşkaya (2022) uncovered a positive effect of various ICT indicators on stock market development. Furthermore, Pradhan (2014) revealed a bidirectional causal relationship between ICT and stock market development. On the other hand, Okwu (2015) disclosed an insignificant relationship between ICT indicators and stock market capitalization.

Pradhan (2014) analyzed the interaction among ICT, stock market development, and economic growth in Asian countries during the 1961-2012 period through panel VAR and uncovered a bidirectional causality between ICT and stock market development. On the other hand, Okwu (2015) investigated the effect of ICT on Nigeria and South Africa over the 1995–2014 period through regression and found that ICT indicators had an insignificant impact on stock market capitalization, but mobile telephone subscriptions had a positive impact on value of traded shares and number of personal computers had a positive effect on stock market liquidity.

Lee et al. (2017) examined the relationship between ICT indicators and stock market development in 81 countries over the period 1998-2014 through regression and found that ICT development is positively associated with stock market capitalization. On the other hand, Lee et al. (2019) examined the relationship between ICT and stock market efficiency in 71 countries between 2002 to 2014 through regression and revealed that stock markets in countries with high

ICT diffusion are efficient while stock markets in countries with low or medium ICT diffusion are not all efficient.

Afshan et al. (2020) studied the relationship between ICT indicators and stock market development in 10 Asian countries (China, India, Japan, Malaysia, Pakistan, Philippines, Russia, South Korea, Thailand, and Turkiye) for the period of 2000-2016 through quantile-on-quantile cointegration and discovered a positive interaction between ICT indicators and stock market development.

Igwilo and Sibindi (2022) investigated the effect of ICT proxied by number of broadband users, mobile–telephone users, Internet users, and fixed telephone users on the development of African stock exchanges in 11 African stock exchanges for the period 2008–2017 through dynamic regression and uncovered a positive effect of ICT on stock market development in African countries.

Suragan and Durmuşkaya (2022) examined relationship between stock market indexes and ICT indicators (fixed telephone subscriptions, mobile telephone subscriptions, and internet users) in G7 and E7 countries (China, Russia, India, Brazil, Turkiye, Mexico, and Indonesia) for the period between 2003 and 2019 through Pedroni and Kao cointegration test and revealed that mobile telephone subscriptions and individuals using the internet have a positive impact on stock markets and their significance.

3. DATA AND METHODOLOGY

This study investigates the causal relationship between ICT indicators and stock market development in the emerging markets during the 2001-2022 period through Emirmahmutoglu and Kose (2011) causality test. The symbols and definitions of the variables used in the econometric analyses are shown in Table 1. In this context, stock market development is proxied by market capitalization of listed domestic companies as a percent of GDP. On the other hand, ICT penetration are represented by indicators of individuals using the Internet as a percent of population, mobile cellular subscriptions, and fixed broadband subscriptions. All these variables are provided from database of World Bank (2024a,b,c,d).

Table 1. Definition of variables (Author own)

Variables	Definition
STOCKDEV	Market capitalization of listed domestic companies (% of GDP)
INET	Individuals using the Internet (% of population)
MCS	Mobile cellular subscriptions
FBB	Fixed broadband subscriptions

The emerging markets are selected based on MSCI (2024) classification considering the data availability and in turn Brazil, Chile, China, Greece, Hungary, India, Indonesia, Korea Rep., Malaysia, Mexico, Peru, Philippines, Poland, South Africa, Thailand, and Turkiye are included in our sample. On the other hand, presence of stock market capitalization and ICT indicators have led us to determine the study period as 2001-2022. The econometric tests of cross-section dependence, homogeneity, unit root, and causality are performed via Stata 17.0 and Eviews 12.0 statistical programs.

The causal relationship between indicators of ICT penetration and stock market development is examined by Emirmahmutoglu and Kose (2011) causality test. Emirmahmutoğlu and Köse (2011) improved the Toda-Yamamoto (1995) causality test for

panel datasets and the test takes account of both heterogeneity and cross-sectional dependency. The following VAR model is estimated for each cross-section:

$$Y_{it} = \mu_i + A_{1i}y_{i\,(t-1)} + \cdots + A_{\rho i}y_{i\,(t-\rho_i)} + \cdots + A_{(\rho+d)i}y_{i\,(t-\rho_i-d_i)} + \varepsilon_{it} \quad (1)$$

where y_{it} is vector of endogenous variables, μ_i is ρ dimensional vector of fixed effects, ρ_i values are optimal lengths, and d_i values are maximum integration values of the variables under consideration.

4. RESULTS AND DISCUSSION

In the section of econometric analyses, the presence of cross-sectional dependence (CD) between ICT indicators and stock market development is examined through tests of Lagrange Multiplier (LM) test by Breusch and Pagan (1980), LM adjusted test by Pesaran et al. (2008), and LM CD test by Pesaran (2004) and the findings of these tests are shown in Table 2. The null hypothesis of cross-sectional independence is declined and the presence of cross-sectional dependency between ICT indicators and stock market development is specified.

Table 2. Results of CD tests (Author own)

Test	Test Statistics	P values
LM	866	0.0000
LM adj.	98.85	0.0000
LM CD	27.94	0.0000

The existence of homogeneity is examined by means of delta tilde tests of Pesaran and Yamagata (2008) and their results are shown in Table 3. The null hypothesis of homogeneity is declined and the presence of heterogeneity is concluded.

Table 3. Results of delta tilde tests (Author own)

Test	Test Statistics	P values
$\tilde{\Delta}$	9.189	0.000
$\tilde{\Delta}_{adj.}$	10.454	0.000

The presence of unit root at the series is analyzed by CIPS unit root test of Pesaran (2007) due to the cross-sectional dependence among the variables and the results of the CIPS test shown in Table 4 uncover that STOCKDEV, INET, MCS, and FBB are I(1).

Table 4. Results of CIPS test (Author own)

Variables	Test statistics			
	Level		First Difference	
	Constant	Constant + Trend	Constant	Constant + Trend
STOCKDEV	1.104	1.929	-6.181***	-4.096***
INET	-0.780	0.599	-2.118**	-5.829***
MCS	0.866	-0.632	-5.734***	-5.164***
FBB	-1.339	-1.931**	-5.590***	-3.743***

*** and ** indicates that it is respectively significant at 1% and 5% level.

The causal relationship between internet usage and stock market development is investigated by means of Emirmahmutoglu and Kose (2011) causality test and the results of the

causality are shown in Table 5. The results of the panel level causality test uncover a unidirectional causality from stock market development to internet usage. On the other hand, the results of the country level causality analysis denote bidirectional causality between internet usage and stock market development in Hungary, a unilateral causality from internet usage to stock market development in Brazil, and a unilateral causality from stock market development to internet usage in Indonesia, Peru, Philippines, and Thailand.

Table 5. Results of causality test between INET and STOCKDEV (Author own)

Countries	INET ↛ STOCKDEV		STOCKDEV↛ INET	
	Test statistic	P value	Test statistic	P value
Brazil	**9.172**	**0.027**	5.895	0.117
Chile	0.134	0.715	0.007	0.934
China	0.962	0.327	1.196	0.274
Greece	0.125	0.723	0.217	0.641
Hungary	**3.273**	**0.070**	**4.028**	**0.045**
India	0.990	0.804	1.671	0.643
Indonesia	0.222	0.638	**4.674**	**0.031**
Korea, Rep.	0.427	0.513	0.009	0.924
Malaysia	1.874	0.171	0.000	0.983
Mexico	0.327	0.568	0.000	0.998
Peru	1.338	0.512	**6.612**	**0.037**
Philippines	4.264	0.234	**22.797**	**0.000**
Poland	0.769	0.857	1.623	0.654
South Africa	1.108	0.775	2.001	0.572
Thailand	0.119	0.942	**10.588**	**0.005**
Turkiye	2.082	0.353	0.027	0.987
Panel	30.677	0.533	**61.403**	**0.001**

The causal relationship between mobile cellular subscriptions and stock market development is investigated by means of Emirmahmutoglu and Kose (2011) causality test and the results of the causality are shown in Table 6. The results of the panel level causality test uncover a bidirectional causality between mobile cellular subscriptions and stock market development. Furthermore, the results of the country level causality analysis uncover a bidirectional causality between mobile cellular subscriptions and stock market development in Chile, Greece, and Turkiye, and unilateral causality from mobile cellular subscriptions to stock market development in Brazil, and a unilateral causality from stock market development to mobile cellular subscriptions in Hungary and Peru.

Table 6. Results of causality test between MCS and STOCKDEV (Author own)

Countries	MCS ↛ STOCKDEV		STOCKDEV↛ MCS	
	Test statistic	P value	Test statistic	P value
Brazil	**8.868**	**0.031**	3.691	0.297
Chile	**3.705**	**0.054**	**5.068**	**0.024**
China	0.317	0.854	2.107	0.349
Greece	**9.689**	**0.021**	**8.503**	**0.037**
Hungary	0.813	0.367	**8.068**	**0.005**
India	3.229	0.358	4.911	0.178
Indonesia	0.919	0.338	0.437	0.509
Korea, Rep.	0.946	0.623	0.230	0.891
Malaysia	5.699	0.127	5.022	0.170
Mexico	2.402	0.493	3.847	0.278
Peru	0.507	0.477	**3.599**	**0.058**
Philippines	0.177	0.674	0.058	0.809
Poland	3.983	0.263	1.001	0.801
South Africa	0.181	0.671	0.314	0.575
Thailand	0.008	0.930	0.087	0.768
Turkiye	**6.419**	**0.093**	**6.316**	**0.097**
Panel	**44.123**	**0.075**	**53.373**	**0.010**

The causal relationship between fixed broadband subscriptions and stock market development is investigated by means of Emirmahmutoglu and Kose (2011) causality test and the results of the causality are shown in Table 7. The results of the panel level causality test uncover a bidirectional causality between fixed broadband subscriptions and stock market development. Furthermore, the results of the country level causality analysis uncover a bidirectional causality between fixed broadband subscriptions and stock market development in Brazil, and unilateral causality from fixed broadband subscriptions to stock market development in Greece, Hungary, and a unilateral causality from stock market development to fixed broadband subscriptions in Chile and Malaysia.

Table 7. Results of causality test between FBB and STOCKDEV (Author own)

Countries	FBB ↛ STOCKDEV		STOCKDEV↛ FBB	
	Test statistic	P value	Test statistic	P value
Brazil	**9.747**	**0.021**	**23.571**	**0.000**
Chile	0.143	0.705	**2.704**	**0.100**
China	0.024	0.877	0.433	0.510

Countries	FBB ↛ STOCKDEV		STOCKDEV↛ FBB	
	Test statistic	P value	Test statistic	P value
Greece	**18.565**	**0.000**	0.990	0.804
Hungary	**8.494**	**0.037**	4.282	0.233
India	0.827	0.661	1.641	0.440
Indonesia	0.195	0.659	0.047	0.828
Korea, Rep.	5.212	0.157	0.721	0.868
Malaysia	0.439	0.932	**16.238**	**0.001**
Mexico	1.658	0.198	0.170	0.680
Peru	0.008	0.928	0.492	0.483
Philippines	0.124	0.724	0.077	0.782
Poland	4.329	0.228	0.705	0.872
South Africa	2.821	0.420	0.578	0.901
Thailand	0.131	0.937	0.593	0.743
Turkiye	3.350	0.187	4.433	0.109
Panel	**49.016**	**0.028**	**54.399**	**0.008**

A mutual interaction between ICT indicators and stock market development is theoretically expected, because use of ICT in the stock markets increases information and transparency for investors and results in more efficient markets and lower costs. On the other hand, the researchers have mainly investigated the impact of ICT indicators on stock market development and uncovered a positive effect of ICT indicators on stock market development (Lee et al., 2017; Afshan et al., 2020; Igwilo & Sibindi, 2022; Suragan & Durmuşkaya, 2022). Furthermore, Pradhan (2014) uncovered a bilateral causal relationship between ICT and stock market development. Therefore, our causality analysis results are found to be compatible with the theoretical expectations and findings of the empirical studies.

5. CONCLUSION

Stock markets have been considerably developed in the world during the last 40 years together with the globalization process. However, increasing globalization has led significant volatility in the stock markets. The economic implications of stock markets have encouraged the researchers to explore the drivers of stock market development. This study investigates the interaction between ICT indicators and stock market capitalization in the emerging market economies.

The results of the panel level causality analysis uncover a unidirectional causality from stock market development to internet usage and a bidirectional causality between mobile cellular subscriptions, fixed broadband subscriptions, and stock market capitalization. On the other hand, the results of the country-level causality analysis indicate that interaction between ICT indicators and stock market development differs among the emerging markets. Our results and the empirical literature point out a feed-back interaction between ICT indicators and stock

market development. Therefore, progress in the stock market development can be achieved through ICT instrument.

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EMPLOYEES' WORK-LIFE BALANCE IN THE CONTEMPORARY BUSINESS ENVIRONMENT IN SERBIA

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Abstract: Work plays a very important role in the lives of people, companies, and society, in general. Individuals value work for the income it provides, but also because it contributes to self-esteem and personal happiness that people feel when they put their competencies to work. Work is important from the point of individual well-being, but it also forms the cornerstone of economic and social development. However, as a very common phenomenon, not only in our country, but in other countries, too, is that work can prevail in the workers family and private life. Many employees may feel unable to make an adequate balance between their work and private life. Because of this, frustration often arises among them as they are aware that they do not spend enough time with their family, or are neglecting their personal needs. In the same time, families are facing with reduced functionality and alienation of family members. The main aim of this paper is to investigate the level of work-life balance in Serbia, and its relation to job stress. The methodology of the research consists of theoretical and empirical analysis. Theoretical research is based on a literature review, while the empirical research is based on the answers of 291 employees from different organizations in Serbia. The data were collected in October 2023. The analysis is performed by implementing PLS-SEM to investigate the relations between work-life balance and job stress, and by descriptive statistics to investigate the level of work-life balance in Serbia.

Keywords: Work-life balance, human resources, stress, job satisfaction, Serbia.

1. INTRODUCTION

Work-life balance (WLB) is one of the most investigated variables in contemporary management and psychological research and theory. Researchers have been performing different investigations on the relation between WLB and other human resources (HR) and organizational practices and employee attitudes, such as flexible working arrangements (Hayman, 2009; Chung et al., 2020); job satisfaction, and job stress (Haar et al., 2014; Kelly et al., 2020; Arulodss et al., 2021; Sharma & Tiwari, 2023); turnover intentions and turnover

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(Thakur & Bhatnagar, 2017; Giauquev et al., 2019; Maharani & Tamara, 2024), and many others. Research has also demonstrated that work-life balance plays an important role in individual's well-being, such as health satisfaction, family satisfaction, and overall life satisfaction (Sirgy & Lee, 2018). WLB is defined as "the individual perception that work and non-work activities are compatible and promote growth in accordance with an individual's current life priorities" (p. 326). It is an important aspect that many employees take into account when they are thinking about their current and future roles and positions in the company. It is not just about the time they spend on the job, but also the level of energy, willingness, and abilities that they can use for their private lives.

The popularity of WLB has increased due to several reasons. Work plays a very important role in the lives of people, companies, and society in general. Individuals work for the income it provides, but also because it contributes to their self-esteem and personal happiness when they put their competencies to work. It is important from the point of view of individual well-being, but it also forms the cornerstone of economic and social development. However, what is a very common phenomenon, both in our country and in other countries, is that work can prevail in the family and private life. Many employees can feel unable to make an adequate balance between work and private life as they need to work too much to earn a larger amount of money, to reach a higher level in the management of a company, or because work tasks are too complex or challenging so they need to commit more time and energy to solve them. Because of this, frustration often arises as people are aware that they do not spend enough time with their family, or they neglect their personal needs. On the other hand, reduced functionality and alienation of members occur in the family, too. WLB has numerous advantages. It can enhance employees' job and life satisfaction, commitment, and engagement, but also reduce stress and burnout, and especially turnover. People can feel a higher quality of their lives. "Employees with WLB intellect their lives are pleased both inside and outside of career and they get to know least conflict struggle among work and non-work roles. From a business perspective, encouraging WLB may fascinate recruits, aid lessen turnover and absenteeism, and upsurge the probabilities of workers enthusiastically involved in "pro-social" behaviors that rise beyond and away from their job necessities" (Nadhiya & Sareena Umma, 2022, p. 37).

The main aim of this paper is to investigate the level of work-life balance in Serbia, and its relation to job stress. The methodology of the research consists of theoretical and empirical analysis. Theoretical research is based on a literature review, while the empirical research is based on a sample of 291 employees from organizations in Serbia. The data were collected in October 2023. The analysis is performed by implementing PLS-SEM to investigate the relations between work-life balance and job stress, and by descriptive statistics to investigate the level of work-life balance in Serbia.

The paper consists of five sections. The introduction is presented in section one. Section two is related to the theoretical background, explaining the problem of work-life balance and the development of hypotheses. The third section represents the methodology of the research, presenting the sample, procedures, data collection, and questionnaire. The fourth section are results of the data analysis, accompanied by a discussion, while the fifth section consists of conclusions, and theoretical and practical implications of the research.

2. THEORETICAL BACKGROUND

Some of the factors that have influenced the growing need for work-life balance are (Rashmi & Kataria, 2022, p. 1028):

(1) profound changes in the labor market,

(2) modification of gender roles,
(3) more contribution of women in the labor force,
(4) augmented prevalence of dual-earner couples,
(5) single parents in the workforce,
(6) longer working hours,
(7) 24/7 communication technology obscuring the lines between work and non-work,
(8) increasing desire for the quality of life.

WLB is the harmony between two completely different roles that an individual performs and is becoming more and more popular in modern conditions. Work-life balance involves two key dimensions, a) role engagement in work and nonwork life and b) minimal conflict between work and nonwork roles (Sirgy & Lee, 2018). The balance is achieved when the employee is equally engaged in and satisfied with his work and family roles. WLB incorporates the following three mechanisms: time balance (equal time devoted to work and family), involvement balance (equal involvement in work and family), and satisfaction balance (equal satisfaction with work and family) (Greenhaus et al., 2003, p. 510).

According to Sirgy and Lee (2018), work-life balance is achieved when "people are fully committed in their various social roles in work and nonwork life. Individuals with work-life balance engage in multiple roles, and experience satisfaction from multiple roles by effectively distributing time and effort across these roles in salient life domains. Individuals engaged in multiple life domains are likely to experience augmentation of power, prestige, resources, and emotional gratification from their multiple roles like role privileges, overall status security, resources for status enhancement, and enrichment of the personality and ego gratification" (p. 234). It is a matter of establishing a balance between the work activity and the personal life of the workers, to avoid the conflict of roles (Lamane-Harim et al., 2023), as the interference between work and personal life causes difficulties to individuals as a result of pressures between both roles. Figure 1 represents an integrative framework for the research of WLB.

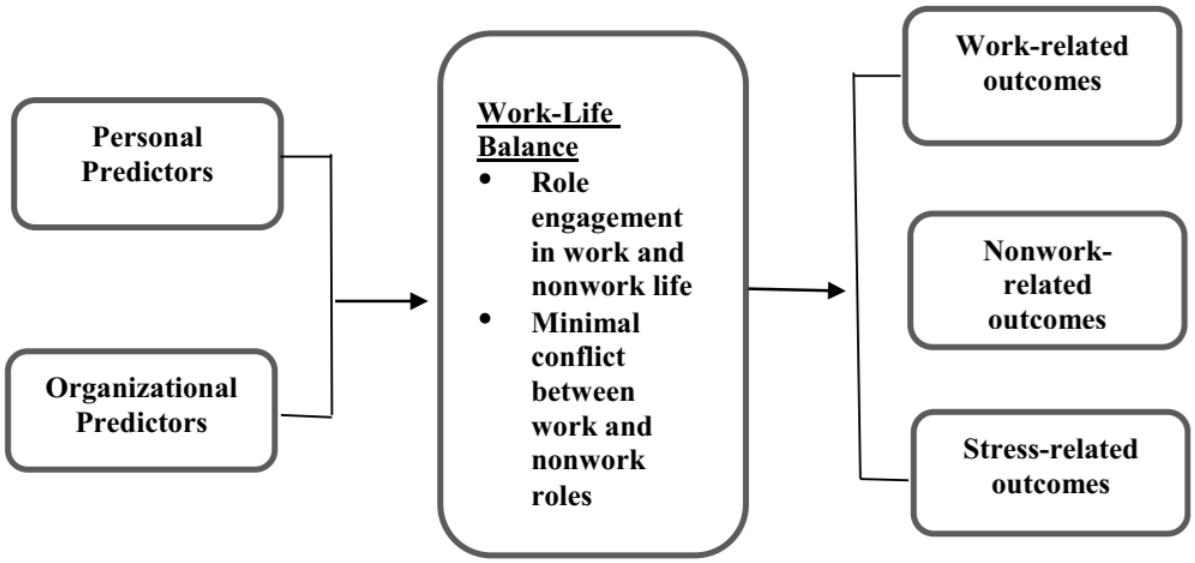

Figure 1. An Integrative Framework of Work-Life Balance (Sirgy & Lee, 2018, p. 233)

Without further explanation of the concept of WLB, the question concerning the effects of WLB on employees and organizations we find more important for this paper. The assessment of the key consequences of work-life balance focused on health, attitudes, and work outcomes

in both the work and non-work domains (mainly in the family). These family and business outcomes include affective conditions, such as dissatisfaction and anxiety, but also behavioral outcomes, such as absenteeism, tardiness, and poor performance (Brough et al., 2014, p. 2725).

A balance between work and personal life can result in higher productivity in an organization through increased individual performance of employees (Konrad & Mangel, 2000; Bloom et al., 2009; Abioro et al., 2018). Balance between work and private life reduces the risk of stress, fatigue, and sickness and prevents better individual well-being.

The causes of the imbalance are various, there are many of them, and based on several previous research, it was determined that they can be described in the following way. Authors Brough et al. (2014) synthesized previous research findings and discussed the occurrence of both, work and family demands as key negative antecedents of work-life balance. More precisely, the perception of sufficient time to meet acute work and family demands is an important issue. Family demands are increased both by the volume of dependent obligations (taking care of children, elderly parents, seriously ill spouses, and other family members) and by specific acute situations that produce intense demands, such as the birth of a baby or sudden serious illnesses of spouses, parents or other members families, as the combination of reduced available time and increased work and family demands creates additional stress for many working parents. In cases of acute family demands, many employees report that where formal provisions for leave from work are available, such leave provision is usually insufficient to adequately respond to these additional family demands, thereby increasing levels of role stress and work-life imbalance (p. 2752).

In their review, authors Allen et al. (2000) described the existence of three groups of consequences of work-life balance (p. 280):

- work-related outcomes (e.g., job satisfaction, turnover intentions, absenteeism, and performance);
- non-work outcomes (e.g., marital, family, and life satisfaction and family performance) and
- stress-related outcomes (e.g., psychological strain, burnout, and substance abuse).

Relations between work-life imbalance/conflict and psychological distress consistently identified a strong positive relationship: increased conflict was associated with increased psychological distress. The experience of strain influenced the levels of work-life conflict. Research has also shown that the relationship between work-life balance and employee turnover is generally stronger compared to the relationship between job satisfaction and balance. This strong association between work-life balance and turnover behavior is explained by the decision of chronically imbalanced employees to seek alternative employment with a more "family-friendly" employer (Brough et al., 2014, p. 2726). Sirgy and Lee (2018) proposed a synthesized view of the main antecedents and consequences of WLB for employees and organizations (Table 1).

Mladenović (2020) emphasizes that the introduction of programs for balancing between work and private life can have the following positive effects (benefits) for employees (p. 75):

- a better understanding of the importance of balance between work and private life,
- better control over business and private life,
- better connections and interpersonal relations at work and outside of work,
- better physical and mental health of employees,
- less stress at work,
- greater job satisfaction,
- higher productivity and commitment of employees,
- greater sense of job security i

– lower turnover.

Table 1. Antecedents and consequences of WLB (Sirgy & Lee, 2018, p. 236)

Antecedents	Consequences
Personal Predictors: • job involvement • job importance • family involvement • conscientiousness • neuroticism • coping style • individualism • power distance • masculinity • uncertainty avoidance Organizational Predictors: • job demand • time pressure at work • job autonomy • role ambiguity • scheduling flexibility • flexible work arrangement • part-time work • assistance with childcare • parenting resources/lactation support • elder care resources • employee health and wellness programs • family-leave policies • social support at work • other services designed to assist employees manage their multiple roles	Work-related outcomes: • high job performance • high job satisfaction • high organizational commitment • high career development and success • low job malfunction • low job burnout • low job alienation • low absenteeism • low turnover intention Nonwork-related outcomes: • high life satisfaction • high marital satisfaction • high family performance • high family satisfaction • high parental satisfaction • high leisure satisfaction • high poor health condition • low conflicts with family members Stress-related outcomes: • low emotional exhaustion • low psychological distress • low anxiety • low irritability • low hostility • low hypertension • low depression • low affective parental distress • low marital distress • low illness symptoms • low somatic complaints • low blood pressure and cholesterol • low alcohol abuse • low cigarette consumption

Satisfied employees will manifest the following positive effects (benefits) for the organization:

– greater responsibility, commitment, and loyalty of employees,
– better teamwork and communication,
– less organizational stress,
– better morale,
– greater organizational productivity,
– less absenteeism and tardiness,
– less leaving the organization and a more stable structure of employees,
– greater retention of the best employees,
– better image of the organization,
– greater customer satisfaction and
– better business results (p. 75).

Based on the aforementioned, and the fact that job stress is commonly mentioned as a variable that is affected by work-life (in)balance, we decided to investigate the relationship between WLB and job stress in a sample of employees from Serbia.

3. METHODOLOGY OF THE RESEARCH

3.1. Sample

Data collection based on the created electronic questionnaire was carried out in October 2023, through the LinkedIn social network. All employees who responded to the questions were asked to declare that they had been living in Serbia at the time of data collection. After the data collection had been completed, it was determined that 316 responses had been collected. By analysing the database and removing incomplete answers, the final sample was reduced to 291 valid answers that were used in further analysis. To mitigate non-response bias, the authors took prior action to reduce non-responses, i.e. stressing anonymity and emphasizing academic sponsorship and survey importance (Berber & Gašić, 2024).

In the sample of 291 respondents, 51% of the respondents were male and 49% were female. The largest share of respondents was between the ages of 35 and 44 (44% of them), followed by those between the ages of 25 and 34 (43%), while a very small share of respondents were between the ages of 45 and 54 (they 7%) and in the group from 18 to 24 years of life (6%). When it comes to the level of education, position in the company, marital status, number of children, and the level of monthly household income, it is evident that the respondents mostly completed high school, 48% of them, while 21% inherited faculties and 29% master's studies, and only 2% were people with a college education. Most of the respondents were not in managerial positions (80%), 57% were married, and 10% were in a common-law relationship, while 32% of the respondents were neither in a relationship nor married. The largest number of respondents did not have children (44%) or had 1 or 2 children (15% and 32%), and the largest share (56%) of respondents indicated that they monthly salary is between 60,000 and 100,000 RSD.

3.2. Questionnaire and research variables

For quantitative research, a questionnaire was created based on previous validated research in this area. The questionnaire was divided into three parts. The first part consisted of questions about the demographic profile: gender, age, level of education, position at work, level of monthly income, marital status, as well as whether respondents have children and how many.

The second part of the questionnaire included questions concerning WLB. We used a questionnaire adapted from Fisher-McAuley, Stanton, Jolton, and Gavin (2003) by Hayman (2005) was used. The questionnaire consisted of 15 questions related to three dimensions of measuring the balance between work and private life. Seven questions referred to *work interference with personal life* (WIPL), four questions referred to *personal life interference with work* (PLIW) and the final four questions referred to *work/personal life enhancement* (WPLE). Higher arithmetic means indicate that respondents experienced that situation more often. For WIPL and PLIW, subscales with higher mean values indicate lower levels of work-life balance. The WPLE subscale is positively worded, and higher mean values indicate higher levels of perceived work-life balance.

In addition to the questionnaire about work-life balance, the third part of the questionnaire contained questions about *stress at work* (Lait & Wallace, 2002), to determine the relationship with WLB.

The respondents answered to the questions within the range of 1–5 on the Likert scale (1 strongly disagree, 5 strongly agree).

3.3. Data processing approach

For the research, we used descriptive statistics to present the sample and overall level of WLB in a sample. The descriptive statistics of the sample were performed using the IBM SPSS Statistics statistical program for data processing. For the determination of the relationship between WLB and job stress, we used the PLS-SEM technique. "PLS-SEM is a causal-predictive approach to SEM that emphasizes prediction in estimating statistical models, whose structures are designed to provide causal explanations. The technique thereby overcomes the apparent dichotomy between explanation – as typically emphasized in academic research – and prediction, which is the basis for developing managerial implications" (Hair et al., 2019, p. 3). The SmartPLS software was used.

4. RESULTS AND DISCUSSION

Based on the data shown in Table 2, it can be concluded that the respondents indicated that they are not in balance regarding the interference of work in private life (WIPL), meaning that the balance is disturbed because the average score is 3.355, which indicates a high-level interference of work in private life. Regarding the interference of private life in work (PLIW), respondents indicated that they were approaching balance here, meaning that the balance was relatively established because the average score 1.9570, indicated a lower level of interference of private life in work. Regarding the improvement of work and private life (WPLE), the respondents indicated that they are approaching balance here, showing that the balance was relatively established because the average score was 3.537, indicating that work and private life had a positive effect on the respondents.

Table 2. Descriptive statistics for WLB (Authors)

	WIPL	**PLIW**	**WPLE**
Mean	3.3554	1.9570	3.5369
Std. Deviation	1.20953	.90275	.95216
Median	3.7143	1.7500	3.5000
Minimum	1.00	1.00	1.00
Maximum	5.00	5.00	5.00

The authors performed a path analysis to investigate reflective constructs and bootstrapping in order to investigate the structural model. In terms of path analysis, the measurement model was tested by using indicator and construct reliability, and convergent and discriminant validities, while the structural model was tested by application of the bootstrapping procedure based on 5,000 subsamples (Berber & Gašić, 2024). This type of measurement was proposed for reflective constructions in the model (Hair et al., 2019). The indicators' loadings between 0.4 and 0.7 should be retained only if their removal did not have an impact on the average variance extracted and composite reliability (Hair et al., 2014). The authors checked the outer loadings of all indicators and found that all reached the minimum level of 0.70 and that all of them could be included in further analysis. However, later analysis of VIF and cross-loadings (Table 3) showed that indicators WIPL5, WIPL6, and WIPL7 had high VIFs (above the threshold of 5.0), and were highly correlated, and therefore they were excluded from the

model. Figure 2 summarizes all of the above-mentioned and shows the retained items (see Figure 2).

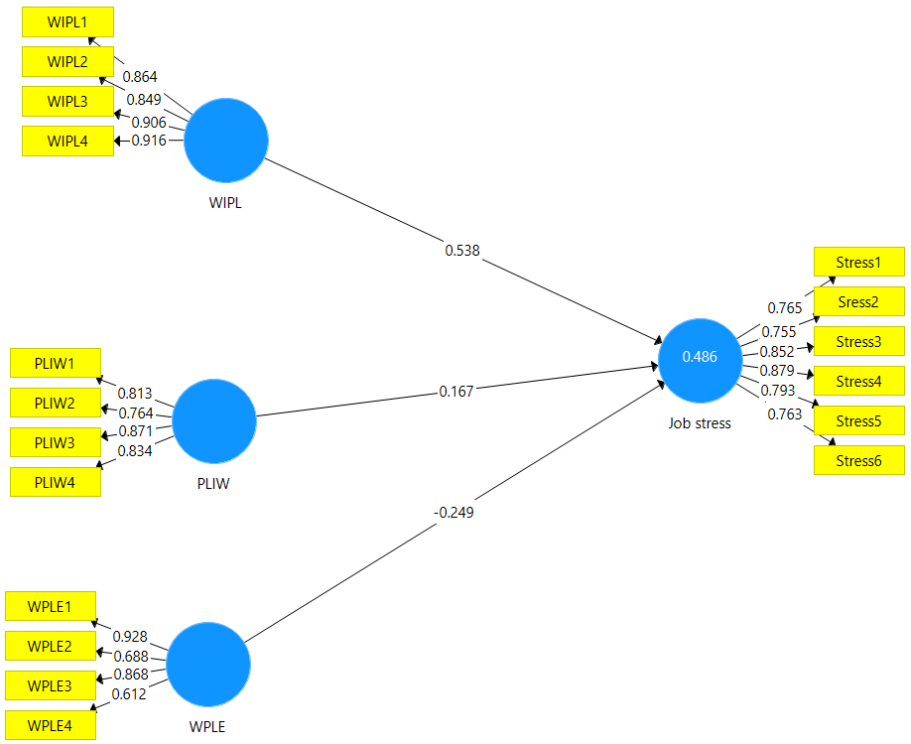

Figure 2. Path analysis diagram (Authors)

Table 3. Outer loadings, variance inflations factors, and convergent validity (Authors)

	PLIW	Job stress	WIPL	WPLE	Cronbach's Alpha	Composite Reliability	Average Variance Extracted (AVE)	VIF
PLIW1	0.813				0.895	0.892	0.675	2.768096
PLIW2	0.764							1.552027
PLIW3	0.871							1.839233
PLIW4	0.834							2.919655
Sress2		0.755			0.889	0.915	0.644	2.080052
Stress1		0.765						2.013452
Stress3		0.852						2.579734
Stress4		0.879						3.143388
Stress5		0.793						2.0062
Stress6		0.763						1.876875
WIPL1			0.864		0.907	0.935	0.782	2.621608
WIPL2			0.849					2.109196
WIPL3			0.906					3.304175
WIPL4			0.916					3.318259
WPLE1				0.928	0.829	0.862	0.616	2.09636
WPLE2				0.688				2.447203
WPLE3				0.868				2.070897
WPLE4				0.612				2.297333

Table 3 outlines the reliability test, Cronbach's Alpha, Composite Reliability, and Average Variance Extracted (AVE). The lowest acceptable limit of Cronbach's Alpha should

be 0.6 (Rahimnia & Hassanzadeh, 2013; Dakduk et al., 2019). The lowest limit of acceptability of Composite Reliability should be 0.7 (Hair et al., 2019; Sabi et al., 2016). *Convergent validity* was assessed by testing *Average Variance Extracted* (AVE), ranging from 0.616 (WPLE), 0.644 (Job stress), and 0.675 (PLIW), to the highest value, recorded for WIPL (0.782). The lowest acceptable limit of AVE was 0.5 (Dash & Paul, 2021). Based on the data in Table 3, the present authors determined that Convergent validity was satisfied for all constructs.

Apart from convergent validity, the authors examined the discriminant validity. Discriminant validity can be assessed by using Heterotrait-monotrait HTMT (Ab Hamid et al., 2017). HTMT ratio values below 0.9 indicate that the defined components are sufficiently different from each other; it means that they describe different phenomena (Hair et al., 2019). The results presented in Table 4 show that all values were below 0.9, so it can be concluded that the discriminant validity criterion is met.

Table 4. Discriminant validity - Heterotrait-Monotrait Ratio (HTMT) (Authors)

	Job stress	**PLIW**	**WIPL**	**WPLE**
Job stress				
PLIW	0.387			
WIPL	0.676	0.333		
WPLE	0.338	0.155	0.173	

The final step was to analyze the relationship between the independent variables (WLB components) and the dependent variables (job stress). R^2 (R-squared), as a statistical measure of the proportion of the variance for a dependent variable that is explained by an independent variable, shows that for Job stress it is 48.6%, explained by the independent variables WIPL, PLIW, and WPLE in the model.

Table 5. Mean, STDEV, T-Values, P-Values (Authors)

	Original Sample	**Sample Mean**	**Standard Deviation**	**T Statistics**	**P Values**
PLIW -> Job stress	0.167	0.169	0.052	3.228	0.001
WIPL -> Job stress	0.538	0.536	0.035	15.449	0.000
WPLE -> Job stress	-0.249	-0.254	0.040	6.234	0.000

The results shown in Table 5 indicate a statistically significant relationship between WLB and job stress. A positive statistically significant relationship was found between PLIW and job stress (β=0.167; t = 3.228; p = 0.001) and WIPL and job stress (β=0.538; t = 15.449; p = 0.000). Besides, a negative statistically significant relationship was established between WPLE and job stress (β=-0.249; t = 6.234; p = 0.000). The relations are presented in Figure 3.

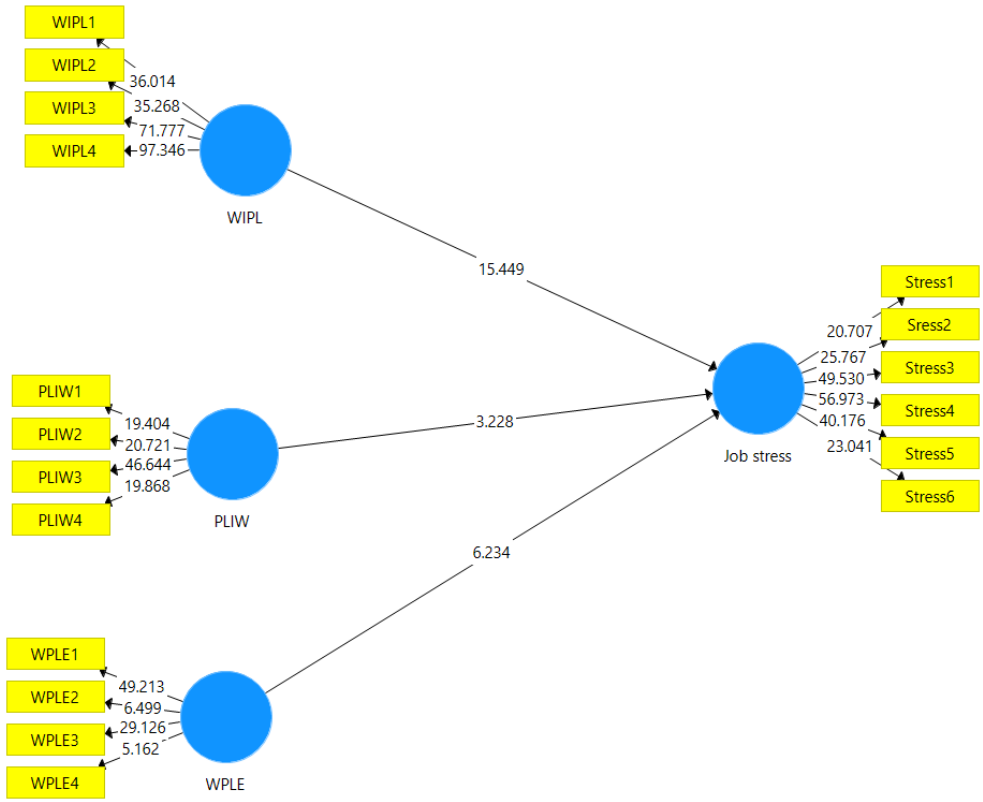

Figure 3. Bootstrapping diagram (Authors)

Based on the results of the analysis, high interference of work in personal life and vice versa will increase job stress. It means that in the case when employees feel that work and private life are in balance, it decreases job stress. The proposed hypothesis is confirmed.

Present results are in line with previous research that also found that balance between work and private life will decrease job stress (Balkan, 2014; Helmle et al., 2014; Sirgy & Lee, 2018; Karani et al., 2022). Helmle et al. (2014) found that organizational initiatives for work-life balance have a negative correlation with job stress. Besides, family problems, financial crises, and conflicts between demands from the company and home are potential stressors for employees at work (Aruldoss et al., 2021). Giauque et al. (2019) found that a high level of satisfaction with work-life balance stands out as having the potential to reduce stress perception.

5. CONCLUSIONS

Work-life balance is a very complex phenomenon and until today it is still in the developing phase in terms of understanding and all elements that could be comprised by it. However, from all previous research, we can conclude that it is important for each person and organization in the contemporary business environment.

The results of this research showed that respondents in Serbia are not balancing their work and private life well, most of them suffer from strong interference of work in their personal life, as indicated in Table 2. Also, we confirmed that WLB is in relation to job stress and that dimension that shows imbalance will increase stress.

Based on all of the above, it is necessary to point out possibilities for improvement of WLB. Measures and recommendations are observed at the individual and organizational levels.

When we talk about the individual level, some of the suggestions are:

- Improve the process of planning your obligations, both family and business, for better coordination.
- Assess your capabilities - don't take on more tasks than you can handle (it's not impolite to say I can't, I'm not getting there).
- Define a list of priorities both in work and in private obligations.
- Take breaks during work, they are not designed for no reason.
- Try to control stress - playing sports, walking, reading literature, watching tv programs that relax you, etc.
- Try to eat healthier and have regular meals.
- Spend time with loved ones, even for a short time, increases the level of happiness.
- Be flexible and ready to adjust plans, because there will always be changes.

On the other hand, there are measures that organizations should implement to help their employees. Some of the measures can be:

- Application of various forms of flexible working arrangements, among which the most common are flexible working hours, working from home, a hybrid work model, reduced working hours, or reduced working week. In this way, the companies would enable the employee to get a certain amount of freedom and authority to allocate his/her working time and thereby provide himself with enough time to meet private needs.
- Design and implementation of special programs to help employees who are at a high level of stress, and facing burnout, as support and care for their mental and physical health at work.
- Provision of various additional benefits such as paid private and health insurance. Employees get additional opportunities and care for health and old age in the future.
- Providing fair and adequate compensation - salary and incentives to employees.
- Providing employees with training and career development, through understanding their goals and needs.
- Facilitating the organization of a kindergarten in the company, or at least paying for a private kindergarten for employees who failed to enroll their children in a state kindergarten can also be of great importance for employees.
- Organization and facilitation of the acquisition and preservation of fitness, physical, and mental health, through payment of membership fees to employees in training and fitness centers or the opening of a gym and sports center in the company itself.
- There are also benefits related to children's education (financing), participation of employees in volunteer work, and the like.
- Organization of events that are not related to work in the company itself - watching important sports matches, celebrating various events, and the like.

Although all the mentioned measures are very necessary considering the results of the research, according to which the majority of respondents could not balance their business and private life well, the reality is that only a few measures were recognized or implemented. Therefore, it is necessary to implement many proposed measures as possible at the individual level, as well as at the organizational level. Certainly, serious approaches such as shortening the working week to 4 days or designing special benefit programs require a detailed analysis of job design, business volume, financial predictions, and the like, to create an adequate model.

The limitations of the work refer to the sample of the research, as it does not represent all employees in Serbia. In the future, sector-focused research is suggested to analyze the level

of work-life balance in Serbia, and its relation to job stress in production and service sector and different employee groups.

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ENTERPRISE RISK MANAGEMENT USING THE FMEA-AHP APPROACH

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Abstract: Risk is an integral part of people's lives and and companies' business. It is often associated with uncertainty because an event can happen but does not necessarily happen. Every decision that managers make carries a certain degree of risk. Therefore, managers must be innovative, flexible and ready to deal with risks. Certain risks can be eliminated or reduced depending on the available capabilities and resources. In today's business conditions and constant changes, for companies to maintain their position in the market, Enterprise Risk Management (ERM) is imperative. The goal of ERM is to recognize all positive and negative factors that can affect the company, thereby increasing the probability of success and reducing the probability of failure to achieve the company's goals. In this paper, the identification of risks in the production company was first carried out using the FMEA method. Then, by applying the AHP method in the Expert Choice software program, the proposed alternatives for ERM were ranked. The obtained results showed that the mentioned measures can greatly improve business operations and significantly mitigate the risks the investigated company faces.

Keywords: risk, risk management, ERM, FMEA, AHP

1. INTRODUCTION

The time in which we live is characterized by complex and unpredictable changes, which affect people's lives and the survival of companies. We are exposed to various risks that can lead to adverse events. Risk is defined as the possibility of damage or loss and includes the factor of uncertainty and its impact on the achievement of the goals (Gustavson, 1998; Kaktins & Arhipova, 2002; Suskevica, 2005; Hillson & Murray-Webster, 2007; Rejda, 2011; Rivza & Pilvere, 2012). All this inevitably points to the necessity of risk management, both from a business and a private perspective.

Effective risk management is essential in a very unpredictable business environment to ensure a company's survival and success (Bartram, 2000; Virglerova et al., 2022). As a result, many organizations use Enterprise Risk Management (ERM) to assess every possible risk and

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determine how much of an impact they may have on the company's value (Meulbroek, 2005; Hoyt & Liebenberg, 2011; Panić et al., 2019).

The study by Kleffner et al., (2003), which included risk managers from public businesses, was a pioneer in the subject of ERM. Liebenberg and Hoyt (2003) determined the elements that encourage companies to use ERM. According to Quon et al., (2012), there is no correlation between the assessed degree of market and economic risk and the performance of non-financial enterprises. Sprčić et al. (2015) created an ERM index to assess the quality level of the ERM process.

Few organizations understand the significance of ERM, particularly in Serbia, and there is still not enough research on this topic. The majority of the existing literature deals with evaluating ERM in financial institutions (Kočović et al., 2014; Vukosavljević et al., 2016; Jelenković & Barjaktarović, 2016). According to Barjaktarović et al., (2017), most companies utilize traditional risk management, while others typically lack an organizational framework capable of supporting the implementation of ERM.

2. RESEARCH METHODOLOGY

The need to assess risks using scientific methods has created the necessity to model different types of risks to quantify them and assess the extent of their impact. In the risk management process, managers have different qualitative and quantitative methods that they can choose based on their application and financial costs and in accordance with the risk that is assessed and the types of results that the organization or individual needs.

Qualitative methods are usually applied first, giving a general risk level indication and using descriptive scales to express potential consequences and the likelihood of the risk occurring. Qualitative methods include brainstorming, the Delphi method, SWOT analysis, interviews, checklists, etc. Quantitative methods use numerical values to determine the consequences and probability of an event. They are applicable in the stages of risk analysis and assessment to calculate the risk level of risks and rank risks. Some of the most famous are FMEA, AHP, sensitivity analysis, decision tree analysis, scenario analysis, Monte Carlo simulation, cost-benefit analysis, etc.

For the research in this paper, FMEA and AHP methods were applied.

2.1. FMEA analysis

FMEA (*Failure Mode and Effect Analysis*) is one of the oldest and most commonly used system failure analysis methods. It was developed in 1949 by the US Army and later applied in the aeronautical and space industries (Vujović, 2009; Panić & Živković, 2024). It is based on the potential errors analysis, i.e. cancellations and their impact on the company's operations. The essence of this method is to consider the failure of each component that can affect the system's operation, all with the aim of preventive action to achieve the defined organizational goals. The FMEA procedure involves the following steps:

1) Identifying the system, components, functions, and processes to be analyzed.
2) Determining methods and approaches for analysis, dividing the system into elements or functions, and determining causes, effects and corrective actions. It is most often carried out using a scale for ranking the intensity of consequences (Table 1), to determine whether the consequences of failure will be minor or serious, which should be given special attention.

Table 1. Consequence intensity rating scale (Vujović, 2009; Panić & Živković, 2024)

Rating	Consequence intensity
1	there are no consequences
2	very weak consequences
3	weaker consequences
4	very little consequences
5	small consequences
6	moderate consequences
7	greater consequences
8	very big consequences
9	intense consequences, with a warning
10	very intense consequences, without warning

3) Risk assessment and corrective action prioritization using the RPN. Risk Priority Number (RPN) enables the prioritization of items that require special attention. It is calculated by multiplying the severity of the damage, i.e. intensity (I), probability of occurrence (P), and detectability of failures (D):

$$RPN = I \cdot P \cdot D \tag{1}$$

The scales shown in Table 2 are used to assess the mentioned parameters, while the scale shown in Table 3 is used to assess the risk based on the RPN.

Table 2. Scales for assessing the intensity of damage, probability of occurrence and detectability (Vujović, 2009; Panić & Živković, 2024)

Intensity (I)		Probability of occurence (P)		Detectability (D)	
Rating	**Description**	**Rating**	**Description**	**Rating**	**Description**
1–2	Negligible	1	Most likely, there will be no failures	1–2	Very high, sure detection
3–4	Little	2–3	Small, just a few failures	3–4	High
5–6	Serious	4–6	Medium, occasional failures	5–6	Medium
7–8	Critical	7–8	Big, failures are almost inevitable	7–8	Low
9–10	Catastrophic	9	Very large, failures are inevitable	8–9	Very low
		10	Almost certain	10	Impossible to detect

Table 3. Risk assessment scale (Vujović, 2009; Panić & Živković, 2024)

RPN	Risk assessment
RPN < 10	The risk is acceptable / No action is required
10 < RPN < 100	The risk is acceptable / The risk can be managed by following the prescribed procedures
100 < RPN < 200	The risk is conditionally acceptable / It is necessary to introduce risk control measures and monitoring
200 < RPN < 400	Unacceptable risk / System shutdown and redefinition required
RPN > 400	Unacceptable risk / The risk cannot be managed

4) Based on the established priorities, it is necessary to determine the actions that must be taken to eliminate/reduce potential failures, primarily those with a high RPN value, who will be responsible for implementing the action, and the execution date.
5) After the actions are taken, check the intensity, probability, and detection again to calculate the revised RPN. Based on this, insight is gained as to whether action is still necessary.

2.2. AHP methodology

The Analytical Hierarchy Process (AHP) was defined by Thomas Saaty as a multi-criteria analysis method for group or individual decision-making. It is based on defining the hierarchy of the problem and determining the weights of all alternatives with respsect to the main goal. The analysis breaks down decision-making into goal, criteria and alternatives (Saaty, 1980; Ćatić, 2009). In the end, a synthesis is carried out, and the coefficients of all hierarchy elements are determined according to a strictly established mathematical model. The sum of the weighting coefficients of the elements at each level of the hierarchy is equal to 1, which allows the decision-maker to rank all elements horizontally and vertically. Each comparison of two hierarchy elements uses the Saaty's scale in Table 4.

Table 4. Saaty's scale (Saaty, 1980)

Definition	Rating
Equal	1
Weak dominance	3
Strong dominance	5
Very strong dominance	7
Absolute dominance	9
2, 4, 6, 8 are intermediate values	

3. RESEARCH RESULTS AND DISCUSSION

Enterprise risk management (ERM) is a comprehensive risk identification, analysis, and assessment process that defines measures for treating identified risks (Rejda, 2011). For the research in this paper, the most significant risks were first identified and assessed using the FMEA method. Then, using the AHP method in Expert Choice software, a proposal for measures to treat the identified risks was presented.

3.1. Risk identification and assessment using the FMEA method

For this research, the methodology of an oral interview was conducted in January 2024 in a company that produces electronic and electric cables and conductors in the territory of Zaječar City (Eastern Serbia). Seven experts took part in the interview, including the director and managers of the most important sectors in the company. Experts have identified the most significant risks in the production, marketing, and finance sector, summarized in Table 5, security risks (Table 6), and other risks (Table 7). Identified risks were assessed using the FMEA method, where the priorities of corrective actions were determined.

From Table 5, it can be seen that several risks exceed the limit of risk acceptance and require additional risk treatment measures. In the production process, *the risk of electricity consumption* was assessed as unacceptable due to the seriousness of the consequences due to the occurrence of the risk and the small possibility of detection before the risk occurs. For this reason, it is very important to plan production activities and harmonize electricity consumption with the production plan. There is also *the risk of unskilled labour*. If the company hires the same, it can lead to major breakdowns and breakdowns. Also, *the risk of outdated equipment* was assessed as conditionally acceptable, and additional measures were necessary. If the company does not invest in regular maintenance and servicing of the machines, it directly affects the business.

Table 5. Risk identification and assessment by sectors

Risk	Cause	Consequences	I	P	D	RPN	Action
PRODUCTION							
Untimely goods delivery	Bad distributors	Production delay	6	3	3	53	Control of delivery dynamics and minimum stocks
Poor product blanking	Using improper tools	Bad product	2	4	6	48	New talc devices procurement
Electricity consumption in kW in relation to kg of product	Simultaneous use of different machines and lighting in plants	Unstable voltage, which leads to the loss of electricity and interruption of production	9	4	5	**180**	Reducing electricity consumption action plan
Outdated equipment	Lack of financial resources for the purchase of new equipment	Frequent breakdowns	7	5	3	105	Procurement of new machines, regular maintenance of machines
Lack of skilled labor	Dissatisfaction with working conditions and level of personal income	Increased labor engagement, workers are hired to work on different machines	6	5	6	**180**	Training of workers to work on different machines, change of working conditions
MARKETING							
New competition emergence	Strengthening the competitive forces	Decrease in market share	4	3	5	60	Attractiveness of the offer
Incompletely defined order	Incomplete purchase order acceptance and poor communication with the customer	Bad product	5	3	5	75	Defining the production order in advance, before it is forwarded to production
Change in sales volume in different seasons	Product range characteristics	Insufficient capacity utilization in the winter months	6	8	2	96	Defining the production plan and adapting it to the situation
FINANCES							
Change in the exchange rate of foreign currencies	Business in foreign currency	Impossibility of using funds	6	2	7	84	Defining the plan and measures for mitigating the effects
Prices change	Changes in copper prices	Defining product prices	6	4	7	168	Continuous monitoring of the stock market and adaptation to changes in it
Customer claims	Crediting customers at checkout	Financial losses	8	2	7	112	Use advance payment

Two risks in the financial sector appear conditionally acceptable: *the change in copper prices* and *customer claims*. Meanwhile, the risks in the marketing sector are in the acceptable zone and can be managed.

Table 6 shows that the *disposal of industrial and hazardous waste* represents a risk that is on the borderline of criticality, and the prevention measures that would reduce this risk are appropriate packaging procurement and cooperation with a licenced company for the disposal

of hazardous waste. Large amounts of environmental pollution can occur in the event of an oil spill or some other hazardous substance. Perhaps it would be more realistic if the risks of injuries at work had a higher rating, but this is not the case in this company because it tries to acquire protection equipment promptly. The structure of the employees is such that the workers have been with the company for a long time.

Table 6. Security risks identification

Risk	Cause	Consequences	I	P	D	RPN	Action
Work injuries	Human errors/carelessness	Interruption of the production process due to lack of workers	4	1	10	40	Timely procurement of appropriate protective equipment
Risk of fire	Incorrect installations, inadequate disposal of flammable materials	Property loss	5	2	6	60	Regular check against fire apparatus; provide space for storing flammable materials
Disposal of industrial and hazardous waste	Inadequate space for waste disposal, lack of packaging for disposal	Environmental pollution	8	2	6	101	Get adequate packaging; waste disposal by the appropriate company

As Table 7 shows, risks whose cause is outside the organization have been identified. Therefore, they cannot be influenced directly to eliminate, but they can be managed through appropriate measures and plans, thus reducing their severity.

Table 7. Other risks identification

Risk	Cause	Consequences	I	P	D	RPN	Action
High workforce turnover	Economic stability of the company; hiring workers to work on more machines	Skilled labor loss	5	2	4	40	Conduct regular employee training
The impact of the war in Ukraine on the way of doing business	Unstable political situation	Impossibility of collecting receivables, untimely delivery of raw materials	4	3	4	48	Securing reliable distributors, cooperation with long-term customers
A narrow assortment of finished products	Competition is taking over a larger segment of the market	Lack of customers, reduced productivity	7	5	2	70	Better positioning in the market

3.2. Reducing the risk effects using the AHP method

It is obvious that certain measures should be implemented in the examined company in order to eliminate/reduce identified risks negative effects. To choose the most favorable action, a decision-making model was created using the Expert Choice software package, where the main goal was defined as "Selection of an adequate measure to reduce the negative effects of risk". The following alternatives are suggested:

- *Recruitment of new workforce* (A_1). The surveyed company currently has more than two hundred employees. However, a large workers turnover has been observed recently due to various factors, primarily due to the strengthening and expansion of the mining company in a surrounding that offers better working conditions. Therefore, the company should consider hiring a new workforce to reduce the effect of employee turnover.
- *Engagement companies to check the new clients' liquidity* (A_2). From the aspect of financial risks, this alternative would greatly contribute to better cooperation with new clients and reduce the risk of inability to collect receivables. By engaging specialized firms to check the liquidity of clients, the company could engage in cooperation with each new client, without fear of not being able to charge for its products later.
- *Regular maintenance and revitalization of machines* (A_3). This company cannot function without its machines, and due to the lack of financial resources and the inability to acquire others, it is imperative that the production process must function. In order for the production process not to suffer, the company must invest in regular maintenance of its machines, as well as hiring companies that deal with it, in order to avoid more serious breakdowns and stoppage of production.

The proposed criteria that alternatives are judged by and prioritized using the AHP method are:

- *Risks recognition and identification* (K_1). Recognizing and identifying the risks in time to reduce their effects is very important. Otherwise, the consequences can be large-scale for the company's operations.
- *Company management* (K_2). For any measure to be implemented, the company management must be open to the suggestions of its employees and "hear" the proposals of the sectors that are best informed about the potential risks that the company is facing.
- *Finances* (K_3). Any implementation of defined measures, plans, and actions to eliminate risks requires significant financial resources. That is why it is necessary for the company to implement measures in a timely manner, so that there are no catastrophic consequences of risks that would require twice as much financial resources for their removal than for the implementation of the measures.
- *Effects of implemented measures* (K_4). After each measure implementation, it is important that the results of the same are evaluated and compared with the planned and that they achieve a positive result.

Figure 1 shows the defined decision-making model, i.e. the hierarchical structure of the main goal, criteria and alternatives. After creating the model, the next step is to evaluate the elements by making pairwise comparisons to derive accurate ratio scale priorities instead of using traditional approaches of assigning weights and establishing priorities. A pairwise comparison is the process of comparing the relative importance or preference of two elements (criteria) with respect to another element (the goal) in the level above.

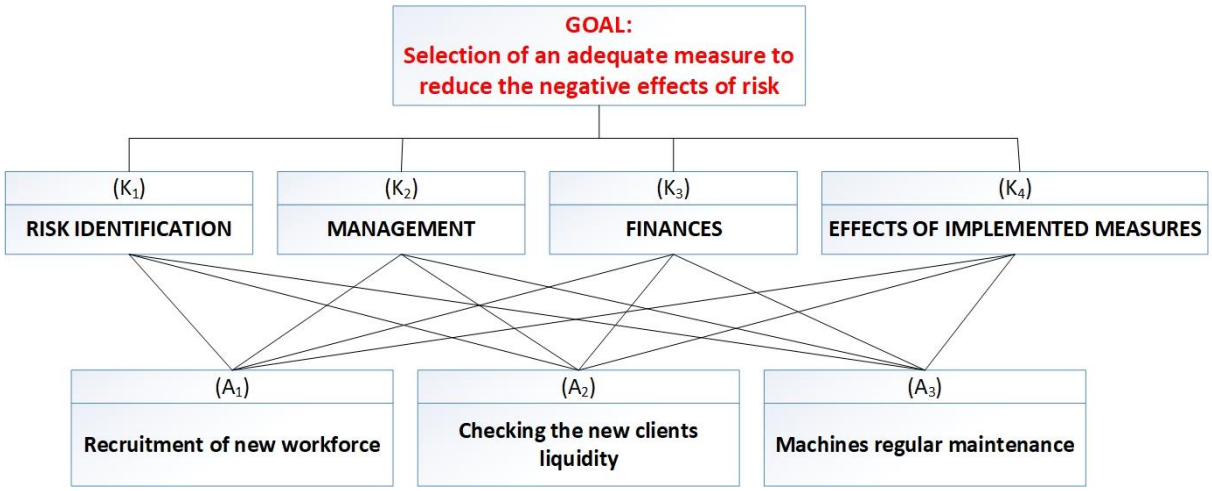

Figure 1. A schematic representation of the defined AHP decision model

First, a comparison of the relative importance of criteria was made (Table 8), where all criteria are compared with each other with respect to the main goal. The obtained weighting factors indicate that the two highest-ranked criteria, K_1 and K_4, have a coefficient of 0.320. The inconsistency ratio is 0.02, less than 0.1 and is considered reasonably consistent.

Table 8. A comparison of the relative importance of the criteria

Priorities with respect to Goal		
K_1	Risks recognition and identification	0.320
K_4	Effects of implemented measures	0.320
K_3	Finances	0.220
K_2	Company management	0.140
	Inconsistency = 0.02	

The next step in the AHP methodology is to compare each alternative with the others concerning each criterion (Table 9). In relation to most of the criteria, alternative A_3 (Regular maintenance and revitalization of machines) has the highest weight coefficient, except for criterion K_1, where alternative A_2 (Engagement companies to check the new clients' liquidity) has the highest preference.

Table 9. Ranking of alternatives based on their mutual comparison with each criterion

		K_1	K_2	K_3	K_4
		Risks recognition and identification	Company management	Finances	Effects of implemented measures
A_1	Recruitment of new workforce	0.143	0.196	0.249	0.250
A_2	Engagement companies to check the new clients' liquidity	**0.571**	0.311	0.157	0.151
A_3	Regular maintenance and revitalization of machines	0.286	**0.493**	**0.594**	**0.599**
	Inconsistency	0.02	0.05	0.05	0.02

Once all judgments are made and priorities are derived, the final step in the AHP method is obtaining overall results, that is, the final ranking of alternatives with respect to the main goal (Table 10).

Table 10. Final ranking of alternatives with respect to main goal

Alternative		Weighting coefficient
A_3	Regular maintenance and revitalization of machines	0.476
A_2	Engagement companies to check the new clients' liquidity	0.318
A_1	Recruitment of new workforce	0.206
	Overall inconsistency	0.03

The alternative assessed as the most necessary to implement is A_3 (Regular maintenance and revitalization of machines) with a participation of 47.6%, which would have the greatest impact on the examined company business. This is followed by alternative A_2 (Hiring companies to check the liquidity of new clients), which would greatly reduce the financial risks faced by the company and contribute to increased productivity and better capacity utilization. The last ranked alternative is A_1 (Employment of new workforce). The implementation of these alternatives requires considerable financial resources. Still, their implementation would contribute to an even better financial result in terms of sold products, better payments from customers, and production would be continuous.

Although the observed company has a very high potential and would be profitable to invest additional financial resources in, it operates as part of a larger organization from Poland. Its management is under the influence of the parent company's management, which somehow prevents the independent realization of the defined alternatives. As seen in the criteria ranking (Table 8), financial resources represent a very big barrier to the implementation of the defined alternatives.

In the long term, improving the business of the examined company would greatly contribute to the overall business of the entire company. The company might be able to expand its capacities and invest in new machines, workers would not quit their jobs, and the factory itself would find quality qualified labour faster.

4. CONCLUSION

Risk is a factor that all organizations face, regardless of the business organization model. Unlike large companies that are aware that risk management is a certainty in doing business, smaller companies may fail to understand risk management as one of the inevitable segments in today's business.

The first step in solving the problem is to recognize the risk. Qualitative methods, such as the FMEA applied in this paper, are very effective for familiarizing the management with possible risks in the company and adequately dealing with them. The paper presents a modified and simple way to apply this method so that the researched company could remain a leader in its business segment with a perceived room for improvement and more efficient business. In addition to the FMEA method, a multi-criteria AHP method was applied to rank alternatives when implementing measures to reduce risk effects. The goal was to prioritize alternatives and criteria to make the best decision. All three alternatives are important and, what is more important, realistically applicable and immediately implementable in the mentioned company. Therefore, the mentioned measures can greatly improve operations and significantly reduce the risks that the company is currently facing, which would, among other things, significantly contribute to improving the living standards of residents in this region.

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Original Research

SMART, ERGONOMIC AND SUSTAINABLE MINING MACHINERY WORKPLACES: AN OVERVIEW OF THE SMARTMINER PROJECT

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Abstract: Despite being the oldest, the mining industry continues to be a major source of pollution, with more people killed or injured than in all other industries. Additionally, social tension related to this sector is widespread around the world, since mining businesses continue to have a significant negative influence on land, water, air, biota, and people through direct and indirect mechanisms. The mining machinery workplaces, which are in the focus of this study have the largest environmental footprint. The dominance of technology-centered design in present research streams is most likely the explanation for the lack of advancement in the mining industry. The SmartMiner project creates shift from technology-centered design and its concept creates solutions for improving the standard of environmental quality in complex systems and suggests a paradigm change to a Human and Data-Centric Engineering. By aligning advanced operator I4.0&5.0 and society S5.0 standards, the SmartMiner project develops solutions for raising the level of environmental quality in complex interactions between physical, behavioural, and organizational processes field. Proposed paradigm can be easily transferred to other industries. The safety of mining machinery operators in their immediate surroundings and their regular alignment with value chain stakeholders are the first steps in our original idea approval process. Research moves to the operator macro-environment, which is determined by organizational contextual factors, and is encompassed by the development of intelligent, ergonomic, non-invasive, and dependable operator aid systems for regulating physical environment job stressors - noise, human vibration, lighting, temperature, air quality, workplace layout issues, etc., with high potential to solve environmental and human health issues and to influence overall performance.

Keywords: mining machinery, workplace, ergonomics, industry 4.0, sustainability

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1. INTRODUCTION

Mining industry today has numerous challenges, problems, and issues, recognized in recent publications, which need urgent solutions. Accordingly, numerous green digital and sustainability transformation solutions are needed, and the SmartMiner project aim to enable step towards smart, ergonomic and sustainable mining machinery workplaces, as in Table 1.

Table 1. Current mining industry challenges and possible solutions

Current Mining Industry Challenges/Problems/Issues	**Proposed Solutions**
Conservative & risky adverse industry which employs 413000 people in EU and 349947 in USA, with more people are killed, injured or with long term health effects than in any other industry, because air pollution increases the risk of having an accident at work (National Institute for Occupational Safety and Health, 2018; Sovacool et al., 2020; Vega-Calderón et al., 2021; Business economy by sector - Mining and quarrying statistics-NACE Rev.2, 2021; Perišić et al., 2022).	Make the oldest industry in the world modern, sustainable and compatible with I4.0&5.0, but mitigate its risks (S5.0), by science & industry & stakeholders /beneficiaries' cooperation, with aim to significantly influence the further development of society and the economy as a whole.
It accounts for 6% of the world's energy demand and 22% of global industrial emissions and seriously causes the destruction of land, water bodies, the atmosphere, vegetation resources and new geological problems that perilously impact human civilization and life (Wang et al., 2021).	
Despite a proliferation of mining industry standards, there is no comprehensive environmental standard and mining machinery is late nearly two generations in comparison to their on-road counterparts (Blengini et al., 2017).	
In 17500 EU mining companies is 5 times less labor productivity then in gas and petroleum sector (Business economy by sector - Mining and quarrying statistics-NACE Rev.2, 2021).	Improve labor productivity to numbers close to similar sectors.
The health cost of the mining activities outweighs its benefits - since 1995 number of employees with cancers, respiratory illnesses (silicosis, asbestosis, and pneumoconiosis…), musculoskeletal injuries, hearing loss, etc. raises (National Institute for Occupational Safety and Health, 2018).	Improve employee's health – reduce employees' illness and health risks of other people living within the surrounding region.
77% of all accidents resulting in a fatality have occurred involved mining machinery with human error as the most frequent cause (ICMM, 2021).	Focus on mining machinery and human error which implies prevention based on interdisciplinary, applied research.
Low level of safety culture as possible cause of high pollution levels, accidents and incidents (Zhang et al., 2020, ICMM, 2021; Tetzlaff et al., 2021).	Analyze safety culture constructs and dimensions (human and organizational factors) to prevent hazards leading to climate changes, pollution, loss of biodiversity and unsustainable use of natural resources.
Mining operations, except mining waste, are regulated at the national level. Serbia has 300 mines; mining sector contributes with share of 2% in the country's GDP, with increase of 6% in the last few years; that inverse is visible in increase of number of companies (+6%), GDP (+25%), innovation potential (41,9%) and employment (+0,5%) (National Qualifications Framework, 2016, Serbian Government, Smart Specialization Strategy, 2020).	Focus primarily on current issues in Serbian mines – on national level.
Novel EU policy documents related to sustainability are particularly important for the mining sector - European Green Deal, EU Climate Law and Pact, New Industrial Strategy for Europe and Circular Economy Action Plan (Blengini et al., 2017; Zhu & Lin, 2021; Puška et al., 2022).	Towards green and digital transition to enable better monitoring, reporting and prevention of air, water and soil pollution and extends mining machine lifetime.
Application of sustainability principles to mining is inherently challenging, as mining is the act of removing and consuming a limited resource. Agenda 2030 (Colglazier, 2015; Blengini et al., 2017; Moomen et al., 2019) and the desired goal of climate neutrality by 2050 is a long way off - sustainable mining is woefully hard to realize, especially in mineral resource-rich developing countries and regarding Sustainable Development Goals 3 and 6.	Field requires an urgent attention from excellent and young scientists, stakeholders and policy makers to fully embrace and pursue the 2030 Sustainable Development Goals (SDGs) agenda, especially in the direction of the progress to decarbonation challenge.

Actions needed to solve current mining industry challenges must deploy Human Factors and Ergonomics (HF/E) solutions offered in digital transformation era. But, according to recent literature research on HF/E in a frame of Industry 4.0 is very scarce in all types of industry

(Reiman et al., 2021; Neumann et al., 2021). A very few HF/E researchers' publications on HF/E in Industry 4.0 are available, however without empirical evidence to support theories and developed models, without any connection to mining industry and without focusing on all organizational levels in mining companies – operational, tactical and strategic. HF/E field is even without mention in the vision of forthcoming Industry 5.0. EU document: *Industry 5.0, a transformative vision for Europe : governing systemic transformations towards a sustainable industry* enumerates and considers projects which deal with workplace conditions, psychosocial factors and stress, but HF/E solutions are not foreseen there (European Commission, Directorate-General for Research and Innovation, 2021). Therefore, The Smartminer project aims to address all above-mentioned challenges, problems and issues recognized in I4.0 concept and I5.0 vision through development of novel, advanced supporting systems based on 1) applied research scientific methods based on experimental measurements and monitoring and 2) economy pushed and society-driven innovation which integrates smart and ergonomic solutions into sustainable mining machinery workplaces.

2. THEORETICAL FRAMEWORK

Most of the research on mining machinery is focused to dynamic modeling of structure and mechanisms and aimed to extend machinery exploitation life (it is over 40 years, which only increases pollution) and reliability and maintenance procedures improvement (Brkić et al., 2014; Rusiński et al., 2017; Tanasijevic et al., 2019), since downtime/stoppage time leads to losses close to 10000EUR/hour (Pantelić et al., 2020). Research in sustainability fields are very rare, although level of greenhouse gases and energy consumption in mining is far from accordance with reduction plans and safety is far from desired (Mirzaei Aliabadi et al., 2018; Ma et al., 2019; Helmers et al., 2020). Safety and pollution are positively correlated and adverse events are dominantly affected by human errors (Vega-Calderón et al., 2021; Mirzaei Aliabadi et al., 2018), while possible future avenues such as exoskeletons and body-worn sensors bring new risks and privacy, perception and acceptance issues (Spasojević-Brkić et al., 2015; Gorgey, 2018; Ghamari et al., 2022). Human errors are caused by numerous unsolved ergonomic issues and it is evident that mining machinery operators and shift/site managers are not satisfied at work (Dempsey et al., 2018; Lööw et al., 2018). As logical consequence there is lower productivity due to operator fatigue and discrepancies between behavioral characteristics and company's organizational culture (Parker et al., 2019; Han et al., 2020). Also, it is noticeable that management practices in the mining sector are under-researched (Street et al., 2019; Balogun et al., 2020) and that corporate governance and social responsibility issues need more scholar attention (Saenz & Romero, 2020; Stojanovic et al., 2020). Similarly, in I4.0 research focus are technical deployments and it is necessary to expand the knowledge to organizational aspects and human-machine interaction – HF/E and management disciplines, with special attention towards avoiding possible superintelligence dangers (Lodgaard & Dransfeld, 2020). Accordingly, our concept goes beyond I5.0 which focuses only human without orientation towards HF/E and organizational context (European Commission, Directorate-General for Research and Innovation, 2021; Maddikunta et al., 2022).

Since there is evidenced obvious lack of addressing human and organizational factors level completely novel The SmartMiner idea goes beyond the state-of-the-art by giving answers to the following questions:

- Is mining machinery downtime caused primarily by technical/technological causes and is there any hidden potential in human and/or organizational factors for solving pollution and accidents issues?

- How to improve productivity of mining machines through higher user (operator) satisfaction, wellbeing, high motivation, and improved workload/organization?
- How to further improve safety in mining machinery operations and prevent environmental degradation, displaced populations, inequality and increased conflict?
- How to further lower mining machinery costs? How to solve challenges connected to extended mining machinery exploitation life such as environmental and health impacts, achieve energy efficiencies, etc.?
- How to make the mining industry a trusted partner for the development of wealth and prosperity in the society? Can all those measures make local communities happier?

Therefore, The SmartMiner aims to involve contextual, systematic approach and integrate human, organizational and technical factors in order to offer, to domestic (and international) industry, technological readiness for innovative, smart mining machinery cabins` concept, which provides comfortable, well organized, unpolluted and safe work for operator and shift/site manager, high business performances for company management, and cleaner and healthier environment for society.

The concept of The SmartMiner is based on a paradigm shift from existing to novel, flexible and scalable solutions based on combination of Human and Data Centric Engineering, matching advanced operator (4.0&5.0) (Gladysz et al., 2023; Bechinie et al., 2024) and society (5.0) (Yao et al., 2024) standards. Our concept, sketched in Figure 1, combines the stakeholder requirements and, at the same time, put the operator wellbeing satisfaction and his sustainable workplace in the center. Operator and his environment represent a set of complex interactions between physical, psychosocial, and organizational factors and processes, which, if mastered could lead to sustainable company performance and people-centric smarter society. Namely, concept starts with operator environmental quality/ wellbeing issues solved by a combination of cyber-physical system, ergonomics and real data analytics. Finally, data analytics and maintenance algorithms should give an input towards society 5.0 by preventing/alarming potential health issues or threats on individual and local community level.

When posting The SmartMiner concept, we had in mind an observation published in (Crawford & Calo, 2016; Janković et al., 2021; Većkalov et al., 2023; Bozkurt & Gursoy, 2023; Yampolskiy, 2024) in sense that "Machines and robots that outperform humans across the board could self-improve beyond our control — and their interests might not align with ours". Broad popular and scientific discourses concern massive use of Artificial Intelligence and Machine Learning appeared. Some could argue that after the learning phase the production process could continue without human intervention (European Commission, Directorate-General for Research and Innovation, 2021; Maddikunta et al., 2022; Chinchane & Mutreja, 2023). This is true but only for stable and repetitive processes, which for sure are not the case in mining industry for now, which is in growing dynamics and uncertainty (European Commission, Directorate-General for Research and Innovation, 2021; Maddikunta et al., 2022). Accordingly, the learning should be employed as a continuous process (emphasized with red circles in Figure 2)! Therefore, the SmartMiner concept is original, novel and based on slogan “Human will be always in center, and we should keep it so”. In a nutshell, we will analyze complex interactions between physical, psychosocial/behavioral aspects of operator and organizational factors and processes. Since concept focuses on environmental quality, we start the analyze by determining operator’s micro and macro Human Factors and Ergonomics – HF/E environment. This is a part of human centric engineering field. The collected data will be analyzed by data centric engineering disciplines. Finally, by means of interdisciplinary human and data centric approaches we will draw significant and applicable conclusions.

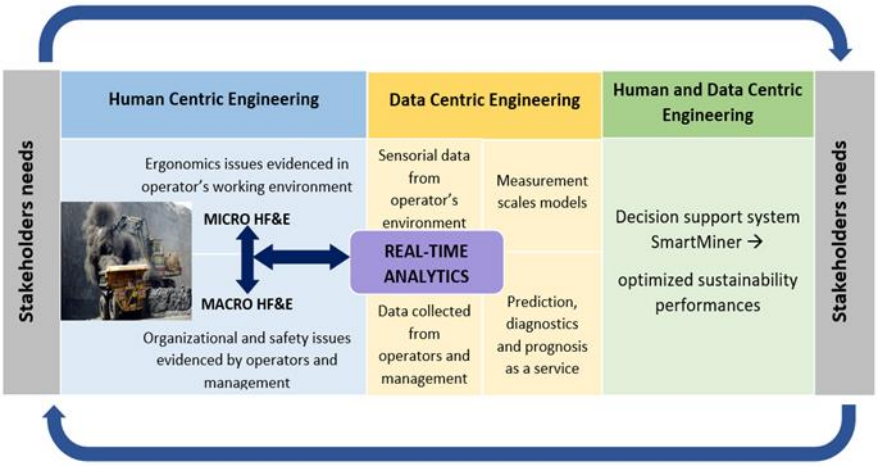

Figure 1. The SmartMiner concept in a nutshell

3. RESEARCH METHODOLOGY

The SmartMiner methodology implied combines multiple design-based research (DBR) cycles and design-based science (DBS), as shown in Figure 2, based on the following hypothesis:

H0: Necessary step between operator 4.0&5.0 and society 5.0 is "management 4.0", which means human (and his environment) in the center and raising environmental quality through micro (physical environment) and macro environment levels (organizational environment).

H1: Level of necessary digitalization and automation of mining machinery workplace depends on contextual factors – primarily on human and organizational factors.

H2: It is possible to prototype innovative support systems: 1. Operator's ergonomic seating adjustment system, serving to solve human factors issues and 2. Smart multi-sensorial operator aid system and software system structural description model as constituent, serving to solve both human and organizational factors issues. Both prototypes are prerequisite parts of commercial Decision Support System.

H3: If level of HF/E, digitalization and automation and contextual factors are aligned, high value of sustainability index must be achieved.

3.1. Research Design

Operator's MICRO environment is represented by his physical environment - noise, human vibration, lighting, temperature, air quality, workplace layout. Its solutions lie in the field of physical and cognitive ergonomics. Job stressors load, if sustained over time, produces adverse effects such as health and safety problems and lack of performance. Operator's MACRO environment is determined by organizational contextual factors - safety awareness, competence and communication on operational and managerial level, organizational environment dimensions, management support, risk judgment and management reaction, safety precautions, accident prevention. This can be overcome by safety trainings and similar and those solutions may lay in the fields of organizational ergonomics and job design. All those factors impair and deteriorate employees' results and sustainability.

Micro and micro levels as physical processes layers are to be connected and balanced by real time analytics - digital processes layers to fit high sustainability performance indicators

(economic, social, environmental etc.). Namely, stakeholders' needs satisfaction starts with data collection. Sensorial network data (although with low failure probability) will be controlled and extended with organizational context and sustainability performance data collected by questionnaires, filled by operators and managers. On micro HF/E level, operator's ergonomic support accessorize for anthropometric adjustment and sensors, which guarantee the necessary comfort in usage, without any invasiveness, and high reliability will be used to improve, measure and control operator's physical environment job stressors (noise, lighting, temperature, vibration, air quality, work place layout etc.), as they represent the first layer of a learning loop and tool to improve overall performance (higher productivity and lower workplace stressors and pollution). It is also important to point out that there are neither privacy nor acceptance issues since sensors are not directed to operator such as in wearable devices but to operator's working environment, while other macro level data will be collected on voluntary, weekly basis by questionnaires. Also, it is important to have in mind that the size of the sensors is of insignificant dimensions in relation to the volume of the cabin of haulage trucks, bulldozers and excavators in mining sector (ISO standard 3411:2010; ISO standard 2860:2010; ISO standard 2867:2013) and they will be placed in accordance to work envelopes. After collection, data are to be undergone to descriptive, predictive and prescriptive analytics to obtain measurement scales and to get prediction, diagnostics and prognosis (preventive alarm function) as a service and as a base of decision support system, which will optimize sustainability performance in the second learning loop ("learning about learning"). Namely, "feedback loops where physical processes affect computations and vice versa", so human stand in the center and cooperate. In that manner both operators' and operations management – productivity, safety, environmental and dispatching issues will be solved through optimized relationship between environment, strategy and structure which leads to both economic results and solutions to environmental and social problems in parallel. The cycle again reaches stakeholders needs and after receiving a positive/negative feedback loop can continue towards sustainability and performance improvement, as in Figure 2.

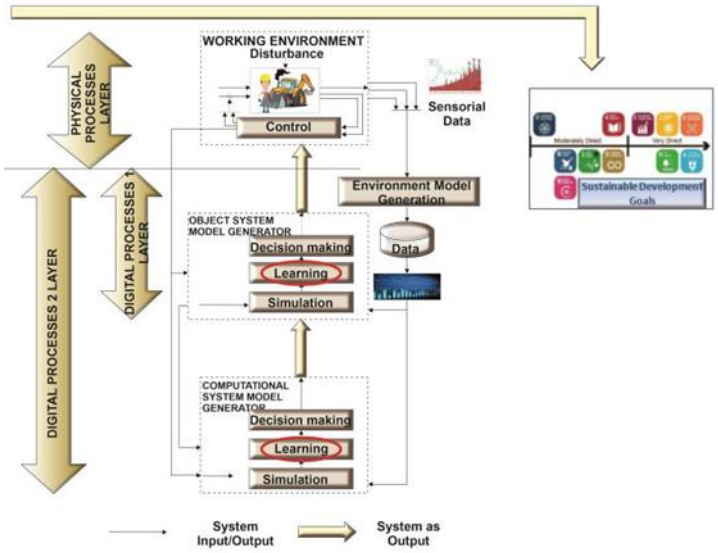

Figure 2. The SmartMiner project methodology paradigm

4. CONCLUSION

The progress beyond the state-of-the art is seen in the "main SmartMiner break-through", by expressing paradigm shift as following:

- The new decision system concept for mining industry, based on machinery characteristics, ergonomic workplace design, smart resources for workplace conditions control, improved work planning procedures and company organization (the SmartMiner paradigm), which is transferable to other industries such as agriculture, logistics, construction, maritime, etc.
- Operator's ergonomic adjustment system as a novel technical solution.
- Multi sensorial aid system (as modular, but integrated tool), which enables the implementation of the paradigm consisting in a unified set of methods for risk management analysis on machine operator workplace through chains sensors-data acquisition-data processing and analysis-improvement of a workplace-increase of productivity.
- Software system structural description model, which covers planning and results on 4 levels – operator, shift/site manager, top management and society and enables strategic or annual work plans realization through real-time measurement system with final aim to improve sustainability indicators (Techno-Economic, Environmental, Societal, Stakeholders and Voluntariness dimensions).

Accordingly, it is expected to increase productivity and wellbeing, based on optimal operators' workplace and proper management decision, as practice today suffers from lack of real-data input in real-time which is crucial for decision makers!

Mining projects have direct and indirect environmental impacts and seriously affect land, water, air, biota, and people, while mining equipment focused in this project has the highest footprint (ISO standard 3411:2010; ISO standard 2860:2010; ISO standard 2867:2013). Beside the fact that mines are visible and can be heard, smelled and felt with all senses, since modern societies need the products of mining, the global mining equipment market size was valued at $125,274 million in 2020, and is expected to reach $165,827.8 million by 2027, growing at a CAGR of 5.7% from 2020 to 2027. Surface mining equipment is expected to be the most lucrative segment, Europe to have the highest - 10% CAGR and metal mining segment to dominate the global mining equipment market throughout 2023-2032 (Chinchane & Mutreja, 2023). In the SmartMiner post-project phase from 2026 much steeper growth is expected, due to paradigm shift resulting in high sustainability index achievement by this project.

The main global benefit and the main positive impact is software system structural description model helpful in decision making on different organizational levels, based on ergonomics and smart support systems in this novel, specific scientific field. It enables improvement and optimization of techno-economic, environmental, societal, aspects of a workplace, stakeholders and voluntariness sustainability indicators while maintaining the highest standards of safety.

Other key impacts of this project for the stakeholders are:

- Solutions and practices considering operator and society 5.0 concepts.
- Environmentally and socially sustainable workplaces.
- Test sites for the benchmarking and the analysis of public acceptance and awareness.
- Change of the stakeholders' mindset: introducing a new way of thinking from the collection of user requirements, to the iterative development and validation of the system's technical specifications, through a pilot demonstration and tests,

through often involvement of different user groups – machinery operators, shift/site manager, top management, crisis managers, resource/infrastructure managers, and public agencies.
- Invigorated key players and investors by diminishing administrative and financial costs which will boost exploration and increase the attractiveness of mining sector, which is of special importance in Serbia.
- Promotion of customized solutions in similar workplaces in other sectors such as agriculture, logistics, construction etc. and easily commercialized.
- Improvement in education and engagement of practitioners, policy-makers and wider society with respect to the mining machinery and sustainability.

Aforementioned facts have direct global impact on the mining, environment, healthcare, safety and economy. Similar industries and indirect impact can be envisioned on climate change, healthcare, research, education, and other aspects of social development.

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DEVELOPING A NOVEL QUANTITATIVE APPROACH TO EVALUATE THE ORGANIZATIONAL FACTORS AFFECTING OCCUPATIONAL HEALTH AND SAFETY IN THE MINING INDUSTRY

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Abstract: The mining industry is among those sectors that urge close attention to occupational health and safety (OH&S). Occupational Health and Safety management promotes many organizational practices based on carefully managing risks and reducing negative occurrences in the production process. Implementing different OH&S practices can also foster significant improvements in working conditions. However, the success of OH&S management efforts depends on workers' attitudes towards OH&S practices and, consequently, their engagement. Although many studies have explored factors influencing occupational health and safety management, few have focused on the mining sector. The main goal of this study is to propose and test measurement instruments for Organizational factors affecting Occupational Health and Safety in the mining sector. The study provides two levels of empirical validation: Exploratory and Confirmatory factor analysis. Exploratory Factor Analysis was conducted using SPSS, while AMOS was employed for Confirmatory Factor Analysis. Exploratory Factor Analysis exposed five factors defined by 21 items. Confirmatory Factor Analysis demonstrated the reliability of the obtained factor structure. The proposed measurement scale resulted in good fit indexes as well as convergent and discriminant validity. The study can significantly contribute to further research in the field.

Keywords: Occupational Health and Safety, Organizational factors, Mining industry, Measurement instrument

1. INTRODUCTION

Occupational Health and Safety (OH&S) is a universal issue in all industrial sectors. Companies constantly invest efforts and resources in order to adequately deal with OH&S problems, aiming to predict risks and prevent damages. Occupational Health and Safety Management aims to establish specific OH&S policies and practices to address OH&S issues adequately (Kim et al., 2019). Adequate management and implementation of OH&S practices

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requires significant commitment and involvement of all human resources in the company and integration of OH&S in all segments of the business production system (Zohar & Luria, 2005; Mohammadfam et al., 2016). The development of OH&S research and practice resulted in the implementing of numerous programs that can bring significant benefits to companies. Multiple benefits result from OH&S practices, including lower costs, less absenteeism, and fewer work interruptions, leading to increased productivity and profits. OH&S management assumes the incorporation of OH&S in job design, process design, HRM function, workers training and development. Including the OH&S elements in all segments of the business production processes contributes to a better organizational culture and acceptance of pro-safety behavior by workers, which improves performance and contributes to the organization's overall goals (Parker et al., 2017). Workers' familiarity with the organization's efforts and workers' perception of the importance of OH&S is necessary for the adoption of an organizational safety culture.

Research dealing with occupational health and safety has a long history (Stavrianidis & Rennie, 1996; Ghosh et al., 2004). Over the years, research has increasingly focused on certain influential aspects concerning, for example, the causes of injuries (Ghosh et al., 2004; Lenné et al., 2012; Liu et al., 2018), lifestyle factors (Sonnentag & Pundt, 2016) etc. The primary focus of research is to understand and anticipate adverse events and take necessary measures to improve OH&S organizational culture. The attention in the studies is directed to certain sectors due to the specificity of the work environment and the different nature of the OH&S problems that may occur (Zohar, 2014). Mining is a sector with extremely high occupational hazards and still many accidents at work, and OH&S represents a critical element of the sustainability of mining practices (Parker et al., 2017; Tetzlaff et al., 2021). A literature review conducted by Nyoni et al. (2019) highlighted that the lack of research in the mining sector is a reliance on secondary data, usually sourced from reports published by companies or regulatory bodies, which raises concerns about the impartiality of the findings. On the other hand, there is a significant lack of empirical research that can provide answers to the questions of whether and how organizational factors contribute to workplace performance in mining organizations at the individual level (Lenné et al., 2012). Therefore, the existing studies do not provide a sufficiently developed measuring instrument for the attitudes of workers in the mining industry about the organizational factors of OH&S. For that reason, this study aims to conceptualize and validate an instrument for measuring organizational aspects of OH&S practices based on workers attitudes.

2. LITERATURE REVIEW

Occupational Health and Safety Management (OHSM) performance measurement often faces significant difficulties (Petersen, 2001). Indicators based on which it is possible to measure the performance of OHSM occupy an important topic for researchers in this field. Haas and Yorio (2016) asked managers how they measure the effectiveness of OH&S practices in mining organizations. The survey consisted of 20 elements related to specific mining risks and hazards, each composed of several practices (133 in total). The results indicated three general types of performance measures: organizational performance, worker performance and interventions.

Nyoni et al. (2019) conducted extensive literature research on organizational factors in the mining industry as a domain that significantly impacts mining worker behavior. The study identified several common organizational factors in the mining industry and confirmed the connection between these factors and the effectiveness of risk control. The organization's vital role in creating a safety culture in the mining industry was emphasized by Tetzlaff et al. (2021), concluding that commitment and responsibilities are shared among all stakeholders (workers,

supervisors, management, unions, insurance...). Hermanus (2007) talked about the importance of OH&S for workers' health in the mining industry because their lives directly depend on their interest in OH&S procedures and rules. Hu et al. (2016) found that the support and following of the OH&S regulations by managers and supervisors significantly affect workers' compliance. Also, lack of unconstrained communication between workers and management about hazards and knowledge about the safe performance of tasks were pointed out as barriers to workers' more effective participation in the OH&S (Hermanus, 2007).

Parker et al. (2017) sought to develop a multilevel measurement instrument in order to deal with the contemporary challenges of the mining industry in Australia by measuring the perception of the impact of multiple factors on OH&S, with particular emphasis on health issues. The results of this research indicate that the positive perception of employees about OH&S is influenced by the safety climate created by managers, supervisors and co-workers, and therefore affects the behavior of individuals themselves and the development of behavior patterns based on health and safety. Antecedents of workers' safety performances were studied by Hadjimanolis et al. (2015). The findings suggest that many organizational practices, such as safety training provided by the firm, safety information available to workers, participation in safety decisions and organizational commitment, are positively correlated with the organization's safety performance.

Research indicates that OH&S management is complex and dynamic and depends on multiple factors. There are numerous interdependencies between the components of OH&S factors, among which it is impossible to bypass management and its commitment to the implementation of OH&S practices, communication about the importance of health and safety, and the attitudes and participation of workers in creating a safety environment (Mohammadfam et al., 2016).

The current research is focused on large mining companies in Serbia that employ, according to the Republic Institute of Statistics, about 30 000 workers. The goal is to propose and test measurement instruments for Organizational factors affecting Occupational Health and Safety, which will examine the current and emerging problems of the mining sector. The effects of organizational factors will be measured through the proposed tool by measuring workers' attitudes in mining companies. Such a measuring instrument can provide a comprehensive overview of OH&S practices and indicate the different levels of responsibility for their implementation, whether it is managers, supervisors or workers.

The following steps were taken to design and test theoretical constructs:

1. An items pool was created based on previous similar research.
2. The factor structure was examined using Exploratory Factor Analysis (EFA) through the use of SPSS (v.25).
3. The factor structure was confirmed by conducting Confirmatory Factor Analysis (CFA) with AMOS (v.22).

3. RESEARCH METHOD

An extensive literature review revealed various relevant indicators for measuring the Organizational aspect of Occupational Health and Safety (Zohar & Luria, 2005; Milijic et al., 2013; Haas & Yorio, 2016; Parker et al., 2017). The goal is to define the main indicators and constructs in order to determine a representative measurement scale. After choosing the initial list of possible indicators, experts - participants of the SmartMiner project iteratively evaluated them. In that process, 35 organizational indicators were selected. Based on the literature review, several organizational factors were assumed, as explained in the text above. All the proposed measures were included in a questionnaire that had to be filled out by workers in mining

companies. The respondents expressed their views of the proposed measures on a five-point Likert scale.

The table Sample size for ±10% precision level where confidence level is 95% and P=0.5 was used to determine the required sample for testing the proposed scale (Israel, 1992; Singh & Masuku, 2014). According to the sample size table, a sample size of 100 subjects is sufficient to test large populations. In order to obtain an adequate number of properly completed surveys, oversampling was applied, and the surveys were sent to respondents from several mining companies in the territory of the Republic of Serbia by random selection.

Finally, the sample for testing the proposed measuring instrument consisted of 106 respondents, the demographic structure of whom is presented in Table 1.

Table 1. Demographic structure of the sample

		Frequency	Percent	Valid Percent	Cumulative Percent
Age	Less than 25 years old	7	6.7	6.7	6.7
	Between 26 and 35 years old	29	27.6	27.6	34.3
	Between 36 and 45 years old	32	30.5	30.5	64.8
	Between 46 and 55 years old	22	21.0	21.0	85.7
	More than 56 years old	15	14.3	14.3	100.0
Gender*	Male	85	81.0	92.4	92.4
	Female	7	6.7	7.6	100.0
Level of education	Semi-qualified	4	3.8	3.8	3.8
	Qualified	11	10.5	10.5	14.3
	Secondary education	61	58.1	58.1	72.4
	Higher vocational	21	20.0	20.0	92.4
	Magistracy/Master's degree	6	5.7	5.7	98.1
	Doctoral degree	2	1.9	1.9	100.0
Total work experience (years)	Under 5 years	19	18.1	18.1	18.1
	Between 5 and 10 years	20	19.0	19.0	37.1
	Between 11 and 15 years	15	14.3	14.3	51.4
	Between 16 and 20 years	15	14.3	14.3	65.7
	Between 21 and 25 years	10	9.5	9.5	75.2
	Between 26 and 30 years	10	9.5	9.5	84.8
	More than 31 years	16	15.2	15.2	100.0
Position in the organization*	Operational management	33	31.4	32.7	32.7
	Operator of working machines	49	46.7	48.5	81.2
	Maintenance worker	19	18.1	18.8	100.0
In my career I experienced an injury at work	No	76	72.4	73.1	73.1
	Yes	28	26.7	26.9	100.0

*There is missing data in the dataset as some of the respondents did not declare their information.

In order to determine the factor structure, an Exploratory Factor Analysis (EFA) was conducted, where all items (35 questions) were tested. First, the suitability of the sample for factor analysis was checked. Kaiser–Meyer–Olkin (KMO) test has a high value of 0.889, while Bartlett's test of sphericity is statistically significant ($p<0.001$), which confirms the adequacy of the sample (Ho, 2006; Coakes, 2013). Principal Component Analysis and varimax rotation with Kaiser normalization as the rotation method were used for factor extraction (Coakes, 2013). As criteria for selecting indicators, the cut-off of 0.50 for factor loading was used, and items with significant loadings on more than one factor were removed (Ho, 2006). Five factors with 21 indicators were extracted, which can explain 82.09% of the variance in the proposed model. The Cronbach's α coefficient values were analyzed against the recommended value of

0.7 to check the internal reliability of the obtained factors. The results of EFA and Cronbach's α values are presented in Table 2.

Table 2. Extracted factors and Cronbach's α values

	Factors				
	1	**2**	**3**	**4**	**5**
Org 1	.922				
Org 2	.942				
Org 3	.943				
Org 4		.910			
Org 5		.724			
Org 6		.891			
Org 7		.925			
Org 8		.910			
Org 9			.898		
Org 10			.900		
Org 11			.942		
Org 12				.912	
Org 13				.931	
Org 14				.928	
Org 15				.923	
Org 16				.848	
Org 17					.786
Org 18					.801
Org 19					.887
Org 20					.897
Org 21					.863
Cronbach's α	.929	.922	.897	.947	.898

Based on the literature, the grouped indicators are defined in the following organizational factors: O1- Co-worker support; O2-Supervisor support; O3-Trainings related to safety and health at work; O4-Management commitment; O5-Rules and procedures on safety at work. In order to validate the obtained factors, a Confirmatory Factor Analysis (CFA) was carried out using AMOS. The obtained results are presented in Figure 1 and Table 3.

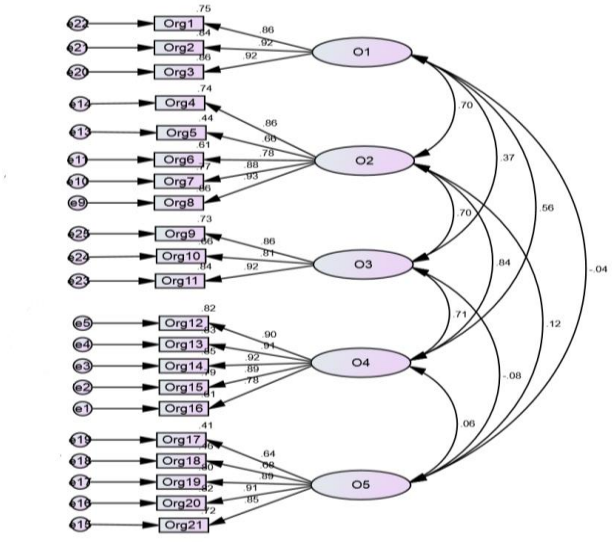

Figure 1. CFA model in AMOS

Table 3. Results of CFA

		Standardized factor loading	**Standard error**	***t* value**	**R^2**	***CR***	***AVE***
O1	Org1	0.864	0.07	13.149***	0.746	0.929	0.814
	Org2	0.916	0.066	15.008***	0.84		
	Org3	0.925			0.855		
O2	Org4	0.86	0.064	13.5***	0.74	0.914	0.683
	Org5	0.661	0.079	8.318***	0.437		
	Org6	0.78	0.084	10.726***	0.608		
	Org7	0.876	0.064	13.993***	0.768		
	Org8	0.928			0.862		
O3	Org9	0.857	0.084	12.57***	0.734	0.898	0.746
	Org10	0.812	0.089	11.324***	0.66		
	Org11	0.919			0.844		
	Org12	0.903	0.109	10.658***	0.816	0.946	0.778
	Org13	0.909	0.108	10.761***	0.827		
O4	Org14	0.923	0.106	10.99***	0.852		
	Org15	0.888	0.09	12.719***	0.789		
	Org16	0.779			0.607		
	Org17	0.637	0.122	7.053***	0.405	0.898	0.641
O5	Org18	0.679	0.111	8.042***	0.461		
	Org19	0.894	0.098	11.688***	0.8		
	Org20	0.907	0.088	11.934***	0.823		
	Org21	0.848			0.719		

*** statistical significance at the 0.001 level

The observed standardized factor loadings have high values as well as t values with statistical significance $p<0.001$. Values of critical ratio (CR) are calculated to confirm composite reliability. Hair et al. (2014) suggested CR values of 0.60 and above to verify that all indicators represent the investigated construct consistently. Average variance extracted (AVE) is used to assess the convergent validity of constructs, the value of which should be above 0.50 (Hair et al., 2014). According to the data presented in Table 3, it can be concluded that composite reliability and convergent validity of constructs have been demonstrated. High R2 values mean that predictors explain a high percentage of their variances.

The discriminant validity of the proposed measuring instrument is checked based on the ratio of correlations between the obtained constructs and the square root of AVE. The condition of discriminant validity is that the correlations between two constructs should be less than the connected square root of the AVE (Hair et al., 2014), which is confirmed by the results presented in Table 4.

Table 4. Discriminant validity of constructs

	O1	O2	O3	O4	O5
O1	**0.902**				
O2	0.696	**0.826**			
O3	0.371	0.7	**0.864**		
O4	0.371	0.843	0.71	**0.882**	
O5	-0.044	0.118	-0.084	0.06	**0.801**

CFA in AMOS also allowed analysis of the fit of the entire model through several goodness of fit criteria. Fit indices CMIN/DF=1.70 CFI=0.942, IFI= 0.943, TLI= 0.929, RMSEA=0.083 are considered acceptable (Hair et al., 2014; Alavi et al., 2020).

Considering the results of EFA and CFA, it can be concluded that an instrument for measuring the organizational factors of OH&S has been obtained.

4. DISCUSSION

This study aimed to define, create and test a measuring instrument that can be used to evaluate the organizational aspect of OH&S in the mining industry. First, a question pool was created based on the literature review, which was distributed as a questionnaire to respondents - workers in mining companies to express their attitudes on OH&S practice. The pilot survey included 106 workers in the mining sector in the Republic of Serbia. Both EFA and CFA were conducted to check the validity and reliability of the resulting measurement instrument.

The results of the analysis indicate that the organizational component of OH&S is a multidimensional construct consisting of five factors that can be measured with 21 items. Factors such as O1-Co-worker support, O2-Supervisor support, and O4-Management commitment were recognized in several studies (Parker et al., 2017; Nyoni et al., 2019). Within factor O1, "Co-worker support", questions related to confidence, communication and help workers receive from their colleagues concerning OH&S were grouped. The group of questions within factor O2, "Supervisor support", presupposes all expected activities undertaken by immediate supervisors to bring closer, demonstrate and empower workers to act according to OH&S practices. Factor O3, "Training related to safety and health at work", has been recognized in the research of Haas and Yorio (2016) and Nyoni et al. (2019), indicating employees' positive attitudes about OH&S training. Factor O4, "Management commitment", recognized by analysis, is the involvement of operational and higher levels managers in activities to create a safe working environment and improve safety culture. O5, "Rules and procedures on safety at work", as a factor was recognized in the works of Haas and Yorio (2016) and Nyoni et al. (2019). However, the items that were singled out within this factor in this research mostly had negative connotations because the questions refer to cases of non-compliance with OH&S procedures, and therefore, the correlation results with other factors have weak or negative values.

5. CONCLUSION

The use of both inductive (EFA) and deductive (CFA) techniques to discover an adequate factor structure allowed a comprehensive and reliable identification of Organizational OH&S factors. The findings presented in this paper may be helpful in more extensive research into the attitudes of workers in the mining industry toward OH&S practices. After identifying organizational factors related to OH&S, the next step in the research can be an examination of the degree of their influence on workers' behavior concerning safety as well as satisfaction at the workplace. Consequently, the interests can focus on insights into the effects of OH&S on various performances. Also, this paper did not examine the potential relationships of organizational factors with other factors, such as technical or human factors, that can significantly affect OH&S in mining companies. Future research addressing these relationships can significantly contribute to understanding obstacles and ways to accept OH&S management and practices and promote sustainable mining operations.

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RELIABILITY-BASED RISK ASSESSMENT OF AUXILIARY MACHINERY IN OPEN-PIT MINES: A BACKHOE LOADER CASE STUDY

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Abstract: Numerous authors have demonstrated the effectiveness of the risk-based approach in the mining sector. However, the majority of earlier research has ignored the role that auxiliary machines, in total risk management play in favor of heavy machinery. This study aims to analyze backhoe loader maintenance data in order to offer a risk assessment approach for auxiliary machinery in open-pit mines. The severity, occurrence, and detection of failures were the three component indicators that together determined the overall risk, as per the FMEA method. The purpose of the Pareto chart was to grade the detection indicator by illustrating the failure type distribution and distinction. The downtime data statistical testing results enabled analytical calculation of the system's reliability and mean downtime, which in turn allowed for the evaluation of the frequency and severity of failures. As a result, a framework for evaluation was put out, supported by data that was gathered, and included a three-dimensional risk assessment matrix. The focus of further research efforts should be on expanding the present sample data in sense of quantity and also to analysis of other machines in the whole mining system.

Keywords: risk, reliability, mining, backhoe loader.

1. INTRODUCTION

Mining is regarded as one of the most dangerous industrial operations, where accidents often happen (Duarte et al., 2019). Accidents encountered there have serious effects, including economic, operational, environmental, and health and safety implications (Mahdevari et al., 2014). The development and deployment of risk assessment methods has the biggest impact on improving mining equipment safety (Tripathy & Ala, 2018). Risk assessment is also required for effective planning to prevent the destruction of equipment and worker potential, as well as the development of a strategy for responding to failure in the framework of prevention consequences. The lack of exact definitions and criteria for indicators in risk analysis and assessment necessitates the development of new risk assessment methodologies (Cheng et al.,

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2021). The unexpected rate of different breakdowns has a major effect on equipment life (Fan & Fan, 2015). As a result, there is a requirement to identify the causes of critical potential failures and the necessary repair or replacement action to prevent them. Reliability analysis is used to estimate the performance of equipment and can be used as an indicator that a potential breakdown will occur (Sakib & Wuest, 2018; Jakkula et al., 2019). In order to reduce unplanned breakdowns and increase safety, it is recognized that new risk assessment approaches can be developed starting with analyzing equipment's availability, reliability and maintainability. This paper is structured as follows. First, comparable prior research has been analyzed in an effort to justify the need for a reliability risk assessment approach. The outcome will eventually be discussed.

2. LITERATURE REVIEW

Backhoe loaders are very popular in mining in the industry for digging, loading, and flattening tasks, as they are often considered auxiliary equipment (Sayadi et al., 2012). But in some cases, when geological conditions and surroundings on the coal mine site are not suitable for large equipment, backhoe loaders can be used as primary mining equipment for digging and loading of coal (Bui & Drebenstedt, 2004).

Pałęga & Rydz (2018) focused on numerous occupational hazards occurring at the workplace of a backhoe loader operator and presented examples of corrective actions to minimize the level of occupational risks there. Jagannath et al. (2013) added that some of those hazards are caused by repetitive action required to operate a backhoe-loader. Madzhov (2019), in his research on the reliability level of backhoe loaders, found that the most common breakdowns on these machines occur due to cam shaft bearing (more than 28 percent) in the group for broken parts, followed by increased oil feeding (more than 17 percent) in the group of incorrectly adjusted parameters. His research also showed that failures due to breakdown of parts make up 56 percent of total breakdowns, and the rest, 44 percent, are due to violations of regulatory parameters (Madzhov, 2019) . To lower maintenance costs, as well as improve the availability of equipment, some authors suggest implementation of total productive maintenance (TPM) and reliability-centered maintenance (RCM) concepts, which focus more on preventing breakdown than repairing equipment after it happened (Palomino-Valles et al., 2020; Bhushan et al., 2022; Spasojević-Brkić et al., 2022). In order to implement predictive maintenance, the most important part of TPM, the first step is the selection of critical breakdowns by analyzing failure data and the proper risk assessment of each kind of breakdown (Cicek et al., 2010). Widely used tools for risk assessment are Failure Mode and Effects Analysis (FMEA) and Failure Mode, Effects & Criticality Analysis (FMECA) (Kumar & Kumar, 2016), but in recent years, more advanced quantitative methods have been developed (Gul et al., 2019; Brkić et al., 2022; Perišić et al., 2023). In the published papers, there are only a few that assess the risk of downtime for the backhoe loader (Misita et al., 2022), especially risks that are based on probability calculation for the downtime and cost of maintenance of these machines. The aim of this paper is to evaluate risk of a backhoe loader's performance in a open-pit mine by applying a reliability-based risk assessment methodology.

3. METHODOLOGY

This study's main concept has been developed into a four-phase methodology. The primary database, which provides the foundation for all subsequent analysis, records the downtime of a backhoe loader during a six-month period. Sorting and classifying the gathered

data according to the kind of outage is the initial stage. In the second stage, the number of failures in a defined period of time will be tested using a chi-square test.

The Kolmogorov-Smirnoff (K-S) test will then be used to test downtime as a random variable. Finding the theoretical statistical distribution that most closely approximates the data is the aim of testing. Based on the findings of the statistical testing, the third phase's approach for determining the reliability/unreliability function will be selected. To clarify, referring functions can be computed analytically if the number of failures in a given period of time can be represented by the Poisson theoretical distribution. Additionally, the downtime distribution will specify the formula that yields the mean downtime required for the study's final stage. Lastly, a three-dimensional risk assessment model will be used to estimate the overall risk associated with the backhoe loader.

4. RESULTS AND DISCUSSION

4.1. Data analysis and classification

To illustrate the distribution of failure types and determine which are more significant, a Pareto chart was created (Figure 1). Downtimes in the observed auxiliary machinery were classified according to the type of downtime: mechanical delay, technological delay, power/electricity delay and delay due to external influences.

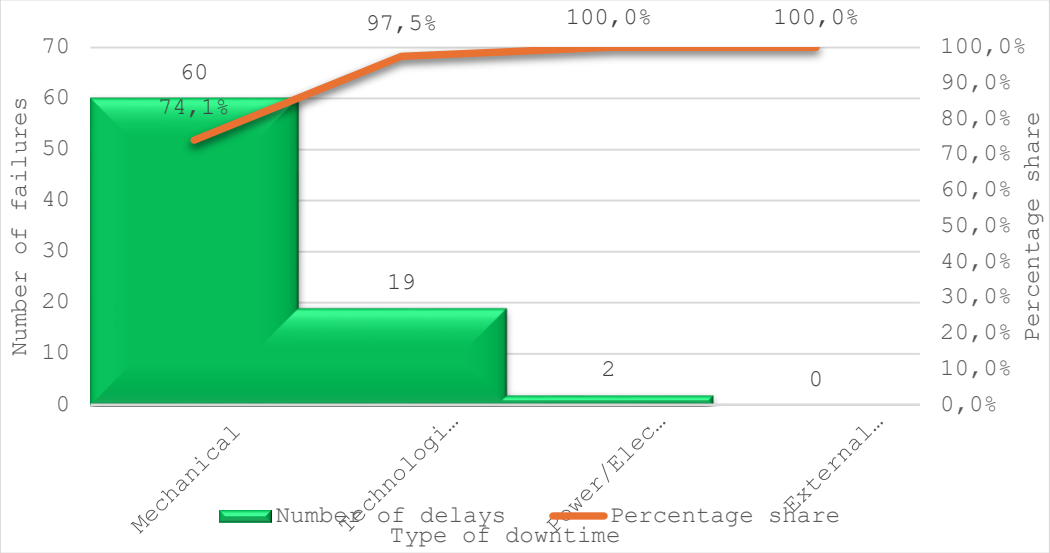

Figure 1. Pareto chart of downtime types

As it can be seen in Figure 1, downtimes related to technology of the process and mechanics account for 97.5% of the sample as a whole, nearly all of which are mechanical in nature. Therefore, from the perspective of maintenance and risk management, these two categories ought to be the most important ones.

4.2. Statistical testing of the data

The Poisson theoretical distribution, with a rate parameter of $\lambda_1 = 0.258727014$ and a relevance threshold of $\alpha = 0.01$, was found to be associated with the number of failures in a given time using the chi-square test (Figure 2). Equation 1 provides the probability density function for the Poisson distribution, which can be used to describe it.

$$f(x) = P(X = x) = \frac{(\lambda \cdot t)^x \cdot e^{-\lambda \cdot t}}{x!}, x = 0,1,2,3. \quad (1)$$

The number of failures in a day, or the random discrete variable *x*, can take values of 0 to 3, which means that there is a chance that there won't be any failures at all, but also 1, 2, or 3. The reliability of the system can be defined as the probability that there won't be any failures in a specific interval of time, therefore equation 2 can be written as it follows:

$$f(0) = P(X = 0) = \frac{(\lambda \cdot t)^0 \cdot e^{-\lambda \cdot t}}{0!} = e^{-\lambda \cdot t} = R(t) \quad (2)$$

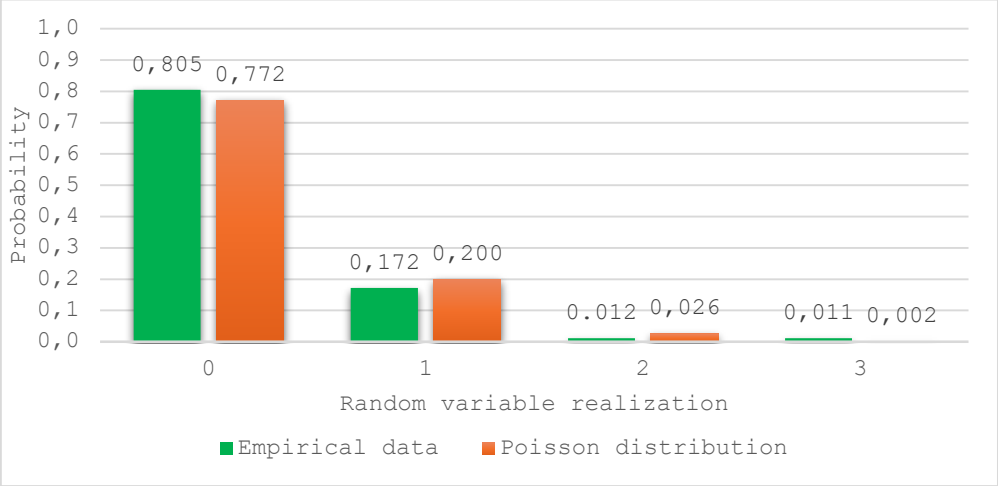

Figure 2. Probability distribution of a number of failures in a day

When it comes to downtime distribution, the results of K-S testing showed that the data can be fitted by The Exponential theoretical distribution (The 1st order Erlang) defined by the rate parameter $\lambda_2 = 0.019667431$ with the relevance threshold of $\alpha = 0{,}01$ (Figure 3). Unit of measurement for delays was a minute. Parameter of the distribution (λ_2) will be equal to repair intensity $\mu_{bl} = 0.019667431$ 1/min.

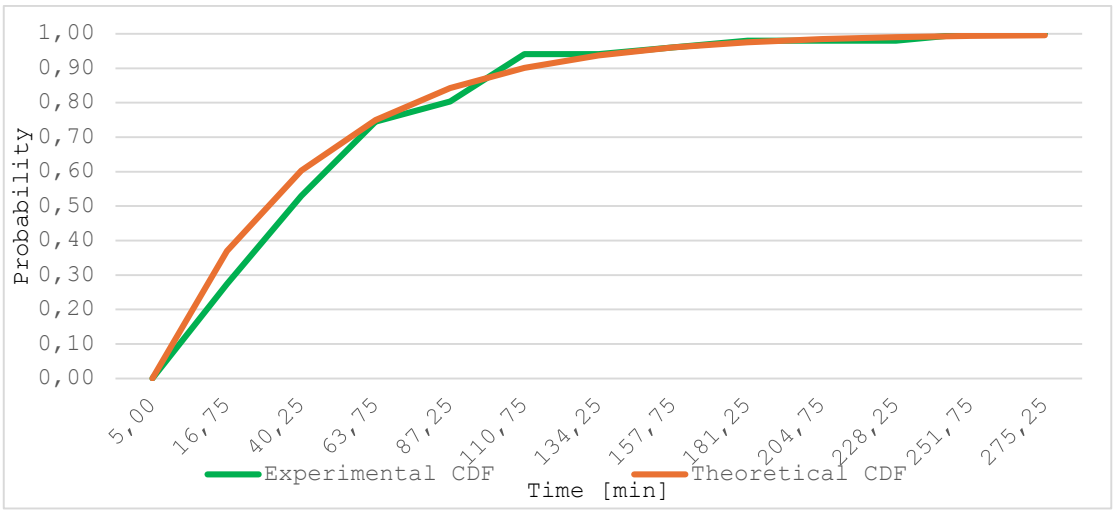

Figure 3. Downtime distribution of a backhoe loader

4.3. Reliability analysis

As previously stated, the backhoe loader's reliability, or the likelihood that it will carry out its intended duty for a specific amount of time, can be obtained from Poisson's PDF equation and has an exponential distribution form. Hence, the parameter of the distribution (λ_1) will be equal to failure intensity (λ_1 = 0.258727014 1/day = 0.010780292 1/h).

$$R(t) = e^{-\lambda_1 \cdot t} = e^{-0.010780292 \cdot t} \tag{3}$$

On the other hand, the idea of unreliability, often known as the failure function, refers to the likelihood that the system will malfunction within a given time range, which can be found using Equation 4.

$$F(t) = 1 - e^{-\lambda_1 \cdot t} = 1 - e^{-0.010780292 \cdot t} \tag{4}$$

Figure 4 provides a graphical representation of the reliability and unreliability functions in a timeframe of one month, approximately 30 days (720 h).

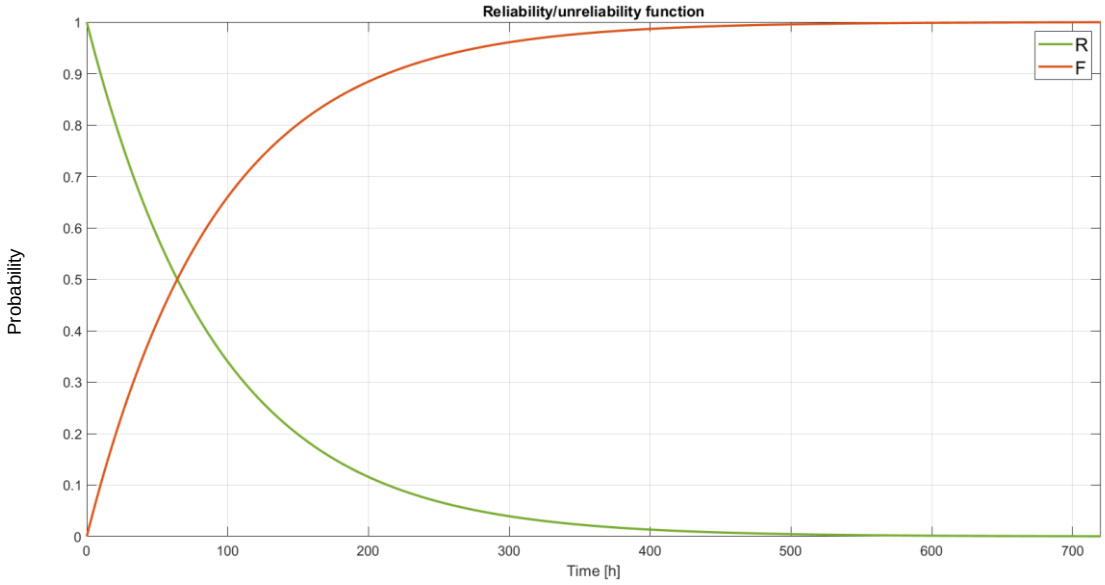

Figure 4. System's reliability and unreliability over time

The average delay time due to the failures (MDT):

$$MDT = \frac{1}{\mu_{bl}} = \frac{1}{0.019667431} = 50.85 \text{ min} \approx 0.85 \text{ h} \tag{5}$$

4.4. Risk assessment model

One of the most approved tools for managing and assessing risk in complex technical systems is the Failure Modes and Effects Analysis (FMEA) method. Official definitions and specifications were provided inside the international standard ISO/IEC 31010. The approach states that the risk level is assessed using the risk performance number (RPN). Three component indicators that accurately represent risk as a whole are included in the risk performance. Each component indicator can be assessed on a 5-point scale. (Djenadic et al., 2022)

The total RPN for all failures is given by Equation 6, and this finally indicates the total risk level in backhoe loaders.

$$RPN = S \cdot O \cdot D \tag{6}$$

In order to accurately assess the incident's intensity, the severity of the consequences (S) is calculated. This indicator seeks to quantify the impact that the current delay has. The total costs (TC) generated due to the backhoe loader's malfunction are used to determine the severity of the failure. Lost revenue and repair expenses are the most significant ones. Research by Bugaric et al., (2022) found that the company loses 66.6125 EUR for every working hour (wh) that a machine is not operating, or that ATC=66.6125 [EUR/wh]. That being said, rankings of the event's severity are presented inside Table 1.

Table 1. Severity of consequences evaluation

Criterion	Severity of consequences	Rank
$TC \leq 100$ [EUR]	Very Low	1
$100 < TC \leq 300$ [EUR]	Low	2
$300 < TC \leq 600$ [EUR]	Medium	3
$600 < TC \leq 900$ [EUR]	High	4
$TC > 900$ [EUR]	Very High	5

Overall severity rank is evaluated by calculating average total costs per failure:

$$ATC \cdot MDT = 66.6125 \cdot 0.85 \ = 56.63 \text{ EUR} \tag{7}$$

As a result, overall severity of consequences is evaluated as Very Low (S=1).

The second partial indicator is O, which stands for the probability of occurrence. It presents the level of ambiguity or the probability that an unanticipated delay or failure may occur. The assessment process based on the system's unreliability is shown in Table 2. To illustrate the significance of this indicator as it varies over time, Table 3 offers four scenarios in which the probability of failure is investigated. On the fifth day of operation, the bulldozer goes into a phase with a "Very High" likelihood of occurrence, which indicates that a failure is nearly certain.

Table 2. Probability of occurrence evaluation

Criterion	Probability of occurrence	Rank
$F(t) \leq 0.2$	Very Low	1
$0.2 < F(t) \leq 0.4$	Low	2
$0.4 < F(t) \leq 0.6$	Medium	3
$0.6 < F(t) \leq 0.8$	High	4
$F(t) > 0.8$	Very High	5

Table 3. Four scenarios that illustrate how second risk dimension (O) changes through time

Scenario	Operating time	Probability of failure	Rank
I	1 day = 24 h	$F(24) = 0.2280$	2
II	2 days = 48 h	$F(48) = 0.4040$	3
III	4 days = 96 h	$F(96) = 0.6447$	4
IV	1 week = 168 h	$F(168) = 0.8365$	5

Detection rate (D), the third partial indicator, quantifies the impact of a failure mode based on how easy it will be to determine its cause when a failure occurs. It also illustrates how a failure mode will be discovered by controls and inspections (Liu et al., 2013) . The ranking of the event detection rate by kind of failure is shown in Table 4.

Table 4. Detection rate indicator evaluation

Criterion	Detection rate	Rank
/	Very High	1
Failure type is mechanical.	High	2
Failure type is technological or due to external influences.	Medium	3
Failure type is due to power/electricity.	Low	4
/	Very Low	5

General detection rate of failures in backhoe loaders is estimated based on an expected value of ranks:

$$EV(R_D) = \sum_{i=1}^{4} p_i \cdot R_{Di} = \frac{60}{81} \cdot 2 + \frac{2}{81} \cdot 3 + \frac{0}{81} \cdot 3 + \frac{19}{81} \cdot 4 = 2.49 \quad (8)$$

As per the previously defined process, which emphasizes safety and requires evaluating each indicator with a whole number, the final detection rate will be rounded up to a greater figure, D=3.

Based on the already defined suggestions in a study by Spasojević-Brkić et al. (2023) a comprehensive risk classification along with suggested actions is given in Table 5. The overall risk of the loader's performance, including the worst-case scenario when it comes to probability of malfunction, is equal to:

$$RPN = S \cdot O \cdot D = 1 \cdot 5 \cdot 3 = 15 \quad (9)$$

Table 5. RPN interpretation

Criterion	Risk level	Suggested actions
$RPN \leq 25$	Very Low	Regular cost analysis once in a year.
$25 < RPN \leq 50$	Low	Cost analysis once in 6 months.
$50 < RPN \leq 75$	Medium	Cost analysis once in 3 months.
$75 < RPN \leq 100$	High	Cost analysis every month.
$RPN > 100$	Very High	Cost analysis as soon as possible.

The primary limiting factor for a machine's economic lifetime is its leasing cost at a market rate of 70 EUR/wh (Bugaric et al., 2022). As a result, when the cost analysis results indicate that the machine maintenance is more expensive than the rental price, i.e., ATC ≥70 [EUR/wh], the machine is no longer economically viable, and replacement is indicated.

In summary, the overall risk assessment is "Very Low," indicating that a yearly cost review is necessary. Figure 5 displays a graphic representation of the loader's highlighted RPN in a three-dimensional danger matrix.

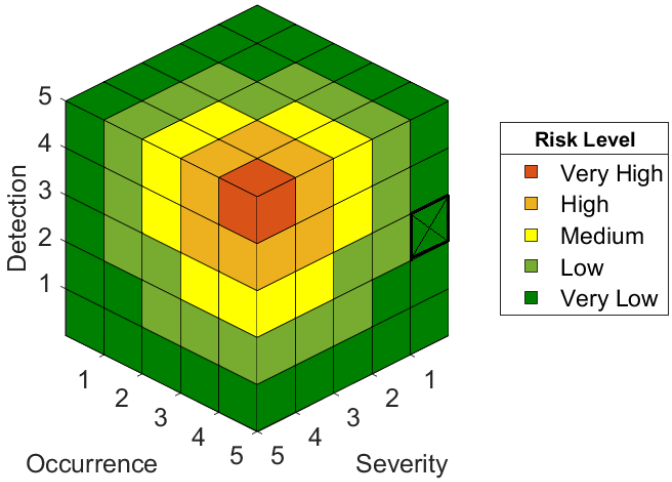

Figure 5. RPN of a backhoe loader in a 3D Risk Assessment Matrix

5. CONCLUSION

According to recommendations from recent research, risk in the mining sector should be assessed from the standpoints of operations and strategy in addition to the widely accepted human-centered viewpoint. The results of the investigation showed that the monitored backhoe loader's use is currently economically justified because it fits in the lowest designated risk class. To clarify, its revenue it generates outpaces its operating expenses. Years of exploitation increase the machine's risk level and diminish the likelihood that it will make a profit. Unplanned machine failures not only have a direct financial impact on the business, but they also cause the amortization process to accelerate. Therefore, using the risk assessment approach to choose whether to buy a new equipment or outsource the replacement of an outdated one can help companies become more aware of the opportunities it presents. The main limitations of this study are the initial limited sample size and the lack of reference risk scores for additional auxiliary machines. Consequently, the focus of further research efforts should be on expanding the present sample data in sense of quantity and also to analysis of other machines and using the established methodology to get wider picture of the whole mining system.

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SELECTION OF AN ALGORITHM FOR THE PREDICTION OF STOPPAGES AND/OR FAILURE OF EXCAVATION UNITS USING SUPERVISED MACHINE LEARNING

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Abstract: The paper presents research into the possibility of applying machine learning algorithms in the prediction of stoppages and/or failure of excavator units. Regression trees, Random Forest and Support Vector Machine (SVM) algorithms were tested with different hyperparameter variations on the collected set of data on the causes and downtime of stoppages of the observed excavator units. The result indicates that the trained SVM algorithm with sufficient accuracy (MSE 0.106) can predict the stoppages of the observed excavator units. Further research is aimed at expanding the database and further improving the possibility of predicting the level of danger for various causes of stoppages and/or failure of the observed excavator units.

Keywords: excavator, stoppage, failure, machine learning.

1. INTRODUCTION

Global mining activities, which deliver about 11% of the world's electricity, are 28% less productive now than they were ten years ago (Ramezani & Tafazoli, 2020). Also, in addition to posing major hazards to the health and safety of the workforce, surface mining systems lead to the large financial losses associated with machines failures (Komljenovic et al., 2008; Horberry et al., 2016; Pantelić et al., 2020).

One of the most often utilized pieces of machinery in surface mining are excavators, which are normally sold for more than many hundred thousand dollars each (Zhou et al., 2019).

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The cost of labor and lost production to the company arises every minute that an excavator experiences a failure (Rudakov et al., 2021).

Machine learning models are increasingly represented in the prediction of important factors for the process of prediction and further decision-making (Jordan et al., 2015; Neu et al., 2022). More and more in the professional literature, machine learning algorithms are represented in the maintenance of technical systems (Carvalho et al., 2019). Different data processing systems and prediction algorithms have been applied in multiple process prediction approaches that have been introduced recently (Neu et al., 2022). However, their application in surface mining is not common (Shitole et al., 2019; Zhou et al., 2019).

For the analysis of excavator failures in order to prevent incidents or accidents, researches using machine learning algorithms, deep learning and similar methods are very few. The reason for this lies in the fact that it is very difficult to collect a large amount of data (on stoppages and downtime) on open pit machinery, which is necessary for training of algorithms, while the majority of traditional manufacturers have historically kept the operating condition data of their excavators private (Zhou et al., 2019). It is not surprising that there aren't many works that are available to the public that suggest anomaly detection techniques for excavators (Zhou et al., 2019).

Therefore, the aim of this paper is to investigate the possibilities of applying machine learning algorithms in the prediction of stoppages and/or failure of excavator units. After the introduction, previous research was presented, and then the Regression trees, Random Forest and Support Vector Machine (SVM) algorithms were tested and compared with different hyperparameter variations over the collected set of data on the causes and downtime of stoppages in the observed excavator units. It is expected that the conclusions of this paper will indicate the choice of the optimal algorithm that provides the most accurate forecast of stoppage and/or failure of the observed dredging units.

2. PREVIOUS RESEARCH

By analyzing sparsely available databases containing individual machine parameters and environmental parameters, machine learning models have the potential to easily identify indications of failure or degradation, and provide predictions of the time frame in which individual parts may fail (Celine, 2017). However, the authors in (Kumar & Srivastava, 2012) point out that even if there is lots of information available about maintenance, its process, and the relevant feedback mechanism, there is currently no appropriate or specially designed expert system available for any particular mining equipment, including excavators. The first attempt is the HAMRISK expert system for risk prevention in transport and mining machines (cranes, excavators, bulldozers, excavators, loaders, etc.), whose hierarchical structure is presented in (Misita et al., 2022),

The authors in (Kumar & Srivastava, 2012) only suggested a framework for failure detection and predictive maintenance of an excavator; no implementation was suggested for the purpose of detecting anomalies in these machines.

The fault tree analysis and a straightforward rule-based system were merged by the authors in (Li & Zhang, 2011; Yin & Mei, 2011).

The authors in (He & He, 2007; He, 2014) employ fuzzy c-means and radial basis function to cluster anomalies and norms, respectively, and rely on principal component analysis and auto-regression with additional output to extract features that reflect anomalies. Nevertheless, it has been demonstrated that these techniques are ineffective when used on intricate and substantial multi-sensor data sets.

A multi-agent system-based framework for excavator problem diagnosis was presented by the authors in (Tang et al., 2012). Nevertheless, their technology has not been put into use or validated—just the general design has been shared.

Kumari et al. (2022) applied Decision Tree, KNN, Random Forest in their research in order to precisely locate trapped excavators or machines under- ground. The solution has been implemented by first proposing the MLAELD (Machine Learning Architecture for Excavators' Location Detection), in which Bluetooth Low Energy (BLE) beacons have been used for tracking the live locations of excavators preceded by collecting the data of the signal strength mapping from multiple beacons at each specific point in a closed area. Second, machine learning techniques are proposed to develop and train multioutput regression models using linear regression, K-nearest neighbor regression, decision tree regression, and random forest re- gression. These techniques can predict the live locations of the required persons and machines with a high level of precision from the last beacon strengths received.

Kurian et al. (2020) show machine learning in incident analysis in oli sands operation.They point out that by prioritizing safety process improvements, identifying the most effective leading indicators—particularly those that may be connected to low-frequency, high-consequence events—and visualizing data and identifying patterns across large datasets in real-time, artificial intelligence and machine learning (AI/ML) have great potential to improve process safety management..

Artificial neural networks, have capability to produce highly accurate predictions, yet people frequently view these models as opaque black boxes (Burkart & Huber, 2021). Decision-making within the "black boxes" needs to be more responsible, transparent, and human-readable (Burkart & Huber, 2021). The authors in (Singh et al., 2016; Burkart & Huber, 2021; Osisanwo et al., 2017) offer crucial definitions as well as a synopsis of the many theories and approaches of explicable supervised machine learning (SML) and give detailed comparisons.

One of the few papers in the wider field shows A Machine Learning-Based Method for Determining the Last-Known Location of Excavators (Kumari et al., 2022), while papers in the field of prediction of failure and stoppages are evidently not frequent. Due to supervised machine learning (SML) advantages, this paper is based on them.

3. RESEARCH METHODOLOGY

In this research, data was recorded on stoppages of excavator machinery at mining pits in Serbia during one year. During the recording period, the operation of three excavator units was monitored and the following were recorded: date, downtime, cause of stoppage, type of stoppage and hours of use. The production years of the observed excavator units are: 2008, 2011 and 2017. All planned and unplanned stoppages were recorded, i.e. stoppages resulting from preventive and corrective maintenance. In the observed recording period, a total of 169 stoppages were recorded on the observed machines. In order to assess the nature of the risk of a stoppage, a panel evaluation method was applied, involving five experts in the field of risk assessment for excavator machinery. With expert ratings from 1 to 10, all stoppages were rated so that a stoppage with a score of 10 represents a stoppage with the highest level of danger (the most probable occurrence of an incident and/or accident). The structure of stoppages and risk assessment using different methods is described in the papers (Misita et al., 2021; Spasojević Brkić et al., 2022; Spasojević Brkić et al., 2023).

In this research, the method of supervised machine learning was applied to the collected research data in order to predict future stoppages, i.e. the cause of the stoppage and/or level of danger. The subject of the research is investigation of the possibility of optimizing machine

learning algorithms and the selection of the algorithm with the best performance, which can further be used to predict the level of danger of stoppage on the observed excavation units.

3.1. Data preparation

The collected series of data on stoppages of the observed excavator units have different structures, therefore some data are quantitatively expressed while others are qualitatively expressed. Table 1 shows the types of data collected.

Table 1. Presentation of the structure of the collected data base

Data category	Data type
Serial number of the data	Quantitative
Machine identification number	Quantitative
Date	Date
Hours of use	Quantitative
Downtime of stoppage and/or failure	Quantitative
Cause of stoppage and/or failure	Qualitative
Type of stoppage and/or failure	Qualitative
Level of danger	Quantitative

Descriptive statistics were first conducted for the observed data set of the variables downtime and expert assessments of the level of danger, where both observed variables are of a quantitative type, table 2.

Table 2. Descriptive Statistics

Statistic	Downtime of stoppage and/or failure	Level of danger
No. of observations	169	169
Minimum	5.000	6.000
Maximum	240.000	9.000
Range	235.000	3.000
Median	30.000	6.000
Mean	47.751	6.538
Variance (n)	3162.991	0.888
Standard deviation (n)	56.240	0.942

Note: none of the failures were rated 1, 2 and 10.

Qualitative data for the variable - Type of stoppage and/or failure refer to one of the following categories of stoppages:

- stoppage of a mechanical nature (mechanical),
- stoppage of a technological nature (technological),
- electrical stoppage (caused by electricity)

Each stoppage in the collected data set was assigned one of the above classifications by type of stoppage, and according to this criterion, three types of stoppages were recorded.

Qualitative data for the variable - Cause of stoppage and/or failure refer to different components of the excavator units where the stoppage or failure occurred. According to the collected data on stoppages in the observed period, it was determined that in the records it is possible to distinguish 36 different systems or components that were the causes of the stoppages. These systems are: reducer, bucket, bucket teeth, alternator, reservoir, tracks, bolt, hydraulics, etc. The aforementioned classification allowed us to perform a kind of grouping of independent variables.

The covariance analysis (ANCOVA test) examined the dependence between the parameters - the level of danger of the observed stoppage and/or failure, the type of stoppage and/or failure and the downtime of the stoppage and/or failure in the sampled data set, and the result is shown in Table 3. According to the observed model, the level of danger is a dependent variable, while the cause of stoppage and/or failure, the type of stoppage and/or failure, and the downtime of stoppage and/or failure are independent variables.

Table 3. Regression of variable Level of danger

Goodness of fit statistics (Level of danger):	
Observations	169
Sum of weights	169
DF	135
R^2	0.856
Adjusted R^2	0.821
MSE	0.160
RMSE	0.399
MAPE	2.389
DW	1.320
Cp	34.000
AIC	-280.168
AICC	-262.407
SBC	-173.751
PC	0.216

The results in Table 3 indicate a high value of the coefficient of determination (R^2 of 0.856) between the level of danger (response variable) and the observed variables (explanatory variables, i.e. the cause of stoppage and/or failure, the type of stoppage and/or failure and the downtime of stoppage and/or failure), which allows us to further test different algorithms.

There are several types of algorithms that can be used for certain situations, and each algorithm can be adjusted via Hyperparameters, so the question is which algorithm to choose and which configuration of hyperparameters should be set in the selected algorithm. In this research, testing of different configurations of hyperpammeters with the observed algorithms was carried out, and the algorithm with the best performance was retained, which is the one with the lowest Bias as a measure of prediction accuracy and Variance measures how noisy the predictions are. Sizes MSE, RMSE, MAPE represent Bias and should have as small values as possible (MSE- mean square error mand of the squared differences between predicted and real, RMSE - Root mean square error, MAPE - Mean absolute percentage error).

The following algorithms were tested:

- Regression trees
- Random Forest
- Support Vector Machine (SVM)

In order to test the proposed algorithms, the software tool XLSTAT was used. In the following text, each of the mentioned algorithms will be presented in detail.

3.2. Regression trees

Regression tree is a non-parametric supervised machine learning method, used for classification and regression. Regression tree is trained by inferring rules for making simple

decisions within a given set of data, with the aim of predicting the value of the required variable. It consists of a certain number of branches, one root and several leaves. Each path from the initial root node, through the internal nodes, all the way to the nodes representing the leaves, actually represents one form of classification, with the conditions found along that path.

Regression tree is often used as a machine learning method within predictive maintenance, today there are many examples of practical applications. Regression tree is suitable for use when the state of a real system needs to be identified or classified (Abdallah et al., 2018). Also, it is used to create models for predicting and forecasting failures. The results show that a simple Regression tree for solving regression problems can be modeled very quickly and at the same time gives good results, even for small databases (Silipo, 2019).

3.3. Random forest

A large number of Regression trees can be combined and trained into one final result called Random decision forest, and such an approach is often encountered, as it does not require too many computer resources to analyse larger databases (Shi et al., 2019). This approach includes multiple independent classes of Regression trees, which jointly decide what the final output value or category will be. As the number of trees within the forest increases, the inference error of the forest converges to the same value. The advantages of Random forest are that it can easily analyse multidimensional data sets, because the categories of training data can be easily partitioned within independent Regression trees. Individual trees very quickly analyse the given categories and learn the relationships between them, and when all the individual results are combined, an output of satisfactory accuracy is generally obtained (Zhang et al., 2019).

Random forest is a supervised machine learning algorithm. This algorithm implies the existence of the so-called forest, which consists of a set of Regression trees, which are mainly trained by the bagging method. The main idea of the packing method is to increase the precision of the final result by combining learning models.

3.4. Support Vector Machine (SVM)

Support Vector Machine (SVM) is a supervised method of machine learning, which is used when the processes that take place within a real system are unknown or due to too many factors, their detailed analysis is unprofitable (Vapnik, 2013). Support Vector Machine (SVM) is a supervised machine learning model designed to solve classification problems, and it can also be used for regression problems and anomaly detection. It is an example of a linear classifier and is mainly used to solve classification problems. In the classification problem, the goal of the classifier is to find the optimal boundary, based on which the input data is separated into several discrete classes and to make this boundary as clearly visible as possible. If a data set is linearly separable, we can classify it using a linear support vector algorithm. However, data in the real world is complex and cannot be solved simply as a linear problem. In this case, the kernel method must be applied to map the original data, then a nonlinear problem is solved with the help of a linear algorithm of support vectors, and the notion of a solid boundary is introduced. Due to the high accuracy in classification, even for non-linear problems, the Support Vector Machine (SVM) has successful applications for face detection, various types of verification and recognition, among others, machine fault detection. (Auria & Moro, 2018).

4. RESEARCH RESULTS

For all three algorithms (RT, RF, SVV) in further experimental research, we examine the accuracy of prediction for the assumed values of independent variables, table 4. For the prediction of the level of danger, a training data set in the ratio of 70:20 was used using the method of N first rows. Qualitative data for the variable Type of stoppage and/or failure contain 3 classes, while the qualitative data for the variable - Cause of stoppage and/or failure contain 36 classes, within each of which we have the qualitative variable Downtime of stoppage and/or failure.

Table 4. Adjusted values of independent variables

Cause of stoppage and/or failure	Type of stoppage and/or failure	Downtime of stoppage and/or failure (min)	Level of danger
bucket	mechanical	120	To be predicted
bolt	mechanical	90	
bucket teeth	mechanical	110	
filter	technological	20	
filter	technological	50	
oil	technological	20	
filter	technological	20	
filter	technological	20	
electrical	electrical	70	

4.1. Regression tree

In order to realize the research, the Regression tree method was first tested. The Regression tree hyperparameter settings are as follows. The chosen method is CHIAD, max tree depth 5, significance level (%) 5, validation N first rows, cross-validation 5 (This means that 20% of the data is used for testing, this is usually pretty accurate i.e. with these parameters, the best performances were obtained. For the set hyperparameters, the following correlation matrix was obtained using the Regression tree algorithm, Table 5.

Table 5. Correlation matrix

from \ to	Downtime of stoppage and/or failure (min)	Cause of stoppage and/or failure	Type of stoppage and/or failure
Downtime of stoppage and/or failure (min)	**1**	0.929	0.041
Cause of stoppage and/or failure	0.929	**1**	0.493
Type of stoppage and/or failure	0.041	0.493	**1**

The correlation matrix indicates a high correlation between the downtime and the cause of stoppage and/or failure (0.93). The algorithm generated tree branching rules, Table 6, which can further be used for prediction. The key indicator of the application of this algorithm is that the downtime of permanent stoppage and/or failure is divided into classes (<= 20, (20; 60], (60; 130], and > 130)) which are key for classifying the level of danger of stoppage and/or failure according to (6.1, 6.46, 7.38, 8.25) consequently.

Table 6. Tree structure

Nodes	Objects	%	Test statistic	p-value	Num DF	Num DF	Split variable	Values	Parent node	Sons	Predicted values
Node 1	161	100.00%	46.044	<0.0001	3	157				2; 3; 4; 5	6,57
Node 2	67	41.61%	0.687	0.410			Time	<= 20	1		6,1
Node 3	65	40.37%	9.873	0.008	1	63	Time	(20; 60]	1	6; 7	6,46
Node 4	13	8.07%	0.438	0.522			Time	(60; 130]	1		7,38
Node 5	16	9.94%	2.059				Time	> 130	1		8,25
Node 6	28	17.39%	0.716	0.810			Cause	machenical; electrical	3		6,79
Node 7	37	22.98%					Cause	technological	3		6,22

Nodes	Level of danger (Pred)	Rules
Node 1	6.570	
Node 2	6.100	If Time <= 20 then Level of danger = 6.1 in 41.6% of cases
Node 3	6.460	If Time (20; 60] then Level of danger = 6.5 in 40.4% of cases
Node 4	7.380	If Time (60; 130] then Level of danger = 7.4 in 8.1% of cases
Node 5	8.250	If Time > 130 then Level of danger = 8.2 in 9.9% of cases
Node 6	6.790	If Time (20; 60] and Cause in [mechanical; electrical] then Level of danger = 6.8 in 17.4% of cases
Node 7	6.220	If Time (20; 60] and Cause in [ttchnological] then Level of danger = 6.2 in 23.0% of cases

The prediction of the level of danger is realized according to the rules given in Table 5.

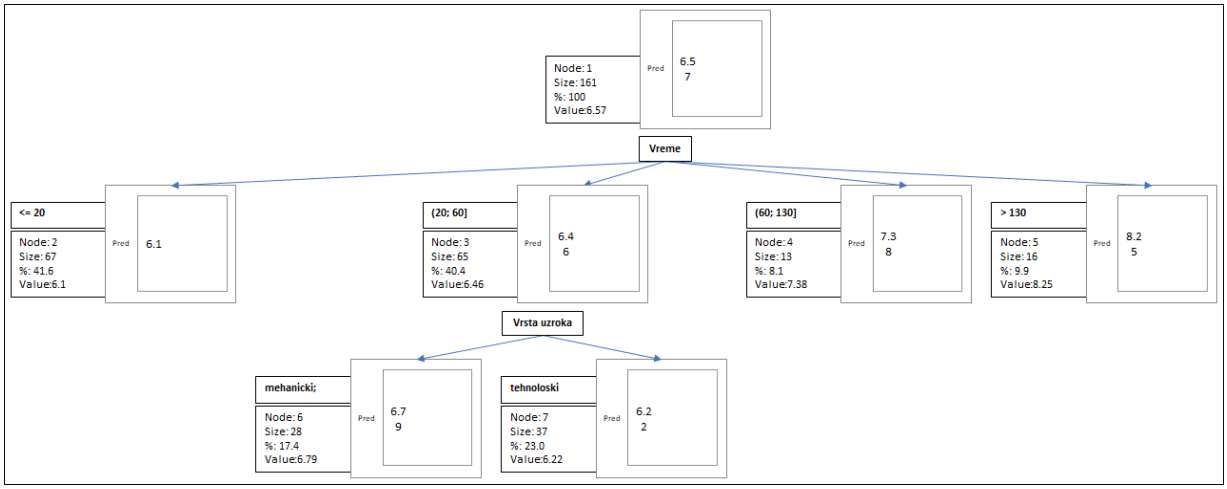

Figure 1. Regression tree

For the set parameters, the MSE using this algorithm is 0.621, while the predictive values of the level of danger are given in Table 7.

Table 7. Prediction of the level of danger using Regression tree algorithms

Cross-validation\ MSE: 0.621				
	Default values for prediction			Prediction
Observation	Cause of stoppage and/or failure	Type of stoppage and/or failure	Downtime of stoppage and/or failure (min)	Level of danger
Obs1	bucket	mechanical	120	7.250
Obs2	bolt	mechanical	90	7.250
Obs3	bucket teeth	mechanical	110	7.250
Obs4	filter	mechanical	20	6.099
Obs5	filter	mechanical	50	6.200
Obs6	oil	mechanical	20	6.099
Obs7	filter	mechanical	20	6.099
Obs8	filter	technological	20	6.099
Obs9	electrical	electrical	70	7.250

4.2. Regression Forest

Setting of RF hyperparameters: method Random input, Mtry – 1 (Mtry 2 and Mtry 3 were tested), Sampling Method – Random with replacement, sample size – 70, Required number of trees in the forest: 120 (150 and 300 were tested). Using the Random forest algorithm, OOB - 0.4 mean squared error validation 0.664 was obtained. Figure 2 shows the movement diagram of the OOB error.

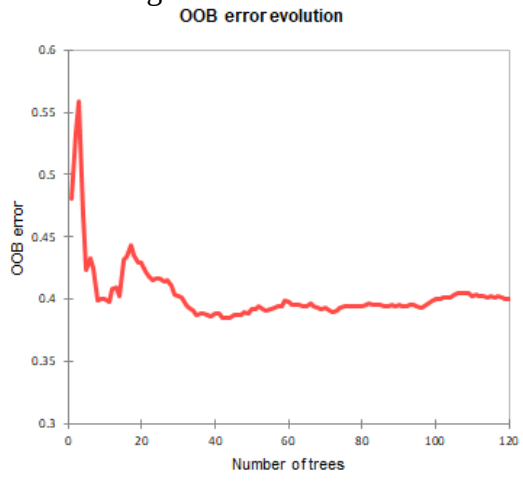

Figure 2. Number of trees

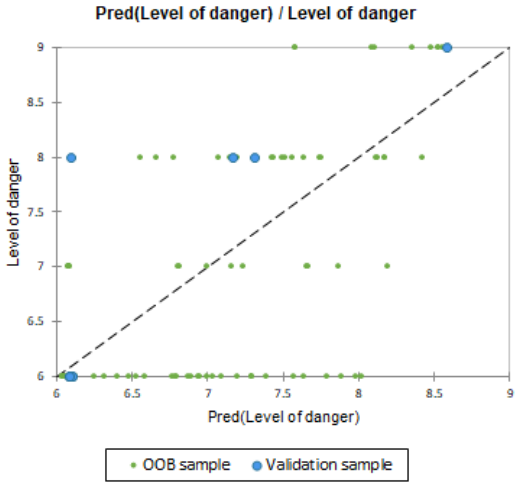

Figure 3. Predictions/OOB sample

The diagram indicates that after 60 trees the error stabilizes, so that is a sufficient number of trees for prediction. Figure 3 shows the prediction deviations from the OOB sample. Variable importance indicates time as the most important variable.

Table 8. Variable importance (Mean increase error)

Variables	Variable importance
Downtime of stoppage and/or failure	11.311
Cause of stoppage and/or failure	10.959
Type of stoppage and/or failure	6.961

Table 9 shows the values of the prediction of the level of danger using the random sum (RF) algorithm.

Table 9. Prediction of the level of danger of stoppages using RF

Cross-validation\ MSE: 0.621				
	Default values for prediction			Prediction
Observation	Cause of stoppage and/or failure	Type of stoppage and/or failure	Downtime of stoppage and/or failure (min)	Level of danger
Obs1	bucket	mechanical	120	7.716
Obs2	bolt	mechanical	90	7.675
Obs3	bucket teeth	mechanical	110	7.892
Obs4	filter	technological	20	6.055
Obs5	filter	technological	50	6.288
Obs6	oil	technological	20	6.047
Obs7	filter	technological	20	6.055
Obs8	filter	technological	20	6.055
Obs9	electrical	electrical	70	6.950

4.3. Support Vector Machine (SVM)

Hyperparameter setting SVM, Quantitative responses type, C - 1, Epsilon - 0.1, Tolerance - 0.001, Linear Kernel method, cross-validation number of folds 5.

The results obtained using the SVM algorithm are given in Table 10.

Table 10. Performance metrics (Level of danger)

Statistic	Training set
MSE	0.106
R^2	0.875
MAE	0.183
Response variable	Level of danger
Number of observations in the training set	159.000
Bias	0.254
Number of support vectors	63.000

Prediction values using the SVM algorithm are given in Table 11.

Table 11. Prediction of the degree of danger of downtime using SVM

Cross-validation\ MSE: 0.621				
	Default values for prediction			Prediction
Observation	Cause of stoppage and/or failure	Type of stoppage and/or failure	Downtime of stoppage and/or failure (min)	Level of danger
Obs1	bucket	mechanical	120	7.818
Obs2	bolt	mechanical	90	7.951
Obs3	bucket teeth	mechanical	110	8.313
Obs4	filter	technological	20	5.930
Obs5	filter	technological	50	6.067
Obs6	oil	technological	20	6.047
Obs7	filter	technological	20	5.930
Obs8	filter	technological	20	5.930
Obs9	electrical	electrical	70	6.999

5. ANALYSIS OF RESULTS

In the research, 3 algorithms with different tuning of hyperparameters were tested. The SVM algorithm was shown as the algorithm with the best performance, MSE is 0.106, and the prediction of the level of danger is given in table 10. The finally set parameters for the SVM can be further used in order to predict stoppage and/or failure of the observed excavator units.

6. CONCLUDING CONSIDERATIONS

The subject research was conducted with the aim of training machine learning algorithms for the prediction of stoppages and/or failures of the observed excavator units and with the aim of preventing incidents and/or accidents on them. Based on the conducted research, a trained algorithm can be used to predict stoppage and/or failure for the observed excavator units. The key conclusions of the research point to the methodology recommended for the prevention of incidents and/or accidents in excavator units, which represents the application of machine learning methods in the prediction of stoppage and/or failure. Another key direction of further research is directed towards the possibility of digitizing the excavator components and collecting a larger amount of data necessary for analysis and training of prediction algorithms.

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Original Research

THE IMPACT OF SAFETY FACTORS ON THE SAFETY SUSTAINABILITY OF OPERATORS IN MINING COMPANIES: A MANAGER'S PERSPECTIVE

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Abstract: The mining industry is a crucial driver of economic development, yet it faces significant challenges due to its hazardous nature. Safety and health at work are paramount for sustainable operations within this industry. This study focuses on managers' perceptions of workplace safety factors concerning mining machinery operators and explores how technical, human, and organisational factors influence mining operators' sustainable safety efforts. A survey was conducted in mining companies to analyse management opinions regarding factors influencing occupational safety and health in mining machinery operators. The data collected was statistically processed using the software package SPSS. Statistical tests were used based on the collected data and opinions of the managers. This research's implications are reflected in the identification of key factors that contribute to the effective implementation of security measures and practices. Despite its limitations, the results offer strong empirical support for the proposed theoretical model. These findings provide valuable guidance for researchers and practitioners seeking to enhance safety in the workplace for mining machinery operators. Through an in-depth analysis of these factors, mining company managers can identify key aspects contributing to the effective implementation of security measures and practices. Finally, a framework will be created that will enable the sustainable management of the safety activities of mining machinery operators, which will result in a reduction in the risk of injury and an improvement in the health of workers in the mining sector.

Keywords: Safety, Technical factor, Human factor, Organisational factor, Sustainability.

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1. INTRODUCTION

Mining is considered one of the most hazardous industries in the world, with a high rate of injuries and illnesses (Haas & Yorio, 2021). According to Marimuthu et al. (2023), mining jobs are among the most unsafe worldwide. The mining industry is characterised by constantly changing working conditions (Bayraktar et al., 2023). Nowadays, mining workplaces are experiencing rapid advancements in technology and techniques, which are affecting the lives of workers in terms of economic and social development. However, despite these developments, safety and health at work in the mining sector is still not up to satisfactory levels (Komljenovic et al., 2017). Mining workers are exposed to various hazards, including biological, chemical, mechanical, and emotional risks (Amponsah-Tawiah et al., 2013).

The entire process of mining exposes miners to many hazards, such as extreme temperatures, injuries caused by mining machinery and falls (Haas & Yorio, 2021). Also, work equipment, mechanization, working environment conditions, and outdated working methods are very critical and lead to accidents (Li et al., 2019).

In addition to all the unfavourable working conditions that cause accidents in mines, one of the biggest causes of accidents is still the human factor, which most often leads to accidents and tragedies (Wang et al., 2019). In this respect, carelessness, unprofessional work, and insufficient training of operators in many ways lead to tragedies (Bayraktar et al., 2023). Therefore, it is necessary to implement all the necessary measures in coordination in order to train, motivate and adapt mining operators to the changing conditions in the workplace.

This research aims to analyse and examine the managers' opinions on the workplace safety factors of the operators of mining machinery. For this purpose, it is necessary to examine how the technical, human and organisational factors of occupational safety and health affect the sustainable safety activities of mining machinery operators. Through an in-depth analysis of these factors, the research will identify key points contributing to the effective implementation of security measures and practices. The aim is to develop a deeper understanding of the interactions between the above factors and their impact on the safety and health of mining machinery operators so that informed guidelines and recommendations can be applied to improve safety standards in mining. The ultimate goal is to create a framework that will enable the sustainable management of the safety activities of mining machinery operators, which will result in a reduction in the risk of injury and an improvement in the health of workers in the mining sector.

2. LITERATURE REVIEW

The available literature investigates safety and health at work, as well as work-related injuries, depending on the industries and the factors included in the analysis. The mining industry carries with it various dangers specific to that area, such as rock strikes and the sudden collapse of rock material, explosions of methane and coal dust, unexpected breakthroughs of water and material, etc. (Zhironkina & Zhironkin, 2023). Also, water pollution, massive waste from mining, soil erosion and land desertification threaten the environment and sustainability (Guo & Yang, 2023). These mining safety hazards threaten employees, equipment, and roadways, interrupt mine production systems, and negatively impact the mining industry's economic benefits and sustainability (Guo & Yang, 2023).

Previous research on safety and health at work clearly shows that certain factors can have a greater impact on the occurrence of accidents or incidents. Zhang (2015) created a safety attitude scale that assesses the safety-related viewpoints of senior managers. Wu et al. (2017) proposed a four-dimensional structure for safety attitudes, including team safety climate, safety

commitment of management, fatalism, and job stress. Hale and Hovden (1998) suggest that managers need to provide both technical and human resources for safety but do not specify how this provision should be managed. In this context, as an essential technological factor, the working environment ensures the safety and health of mining machine operators (Komljenovic et al., 2017). It enables operators to feel more secure in carrying out their daily tasks, leading to a reduction in errors and defects. Also, a safe working environment increases productivity, which improves the quality of products or services, and this all leads to the sustainability of mining operations (Haas & Yorio, 2021). Providing a safe working environment for employees can increase their motivation and commitment, making them feel supported and valued by the company (Montibeller & Von Winterfeldt, 2015). Also, operators who work in a safe and healthy environment are more likely to be satisfied with their work and the company, which can increase operators' performance (Gowrisankaran et al., 2015).

Also, an important aspect of safety and health at work for mining machine operators is the support of managers. The interaction between management and operators involves several factors, including the overall climate of labour relations, the level of concern management shows for their workers, and the support workers receive for safety-related actions (Parker et al., 2017). Gaertner et al. (1987) discovered a direct correlation between poor communication and cooperation between managers and employees and workplace injuries. Their study revealed that companies with a negative labour relations climate have an injury rate that is almost twice as high as companies with a positive labour relations climate. In mines where management neglects employee well-being, accidents are common. Many studies have shown that in all mines with a low accident rate, the union supported the company's enforcement of safety rules (Beus et al., 2016). Coworker support in occupational safety and health indicates the degree of attention shown by coworkers (Parker et al., 2017).

Furthermore, Marimuthu et al. (2023), in their research, indicate that an organisation's performance is greatly influenced by the health and safety of its workers. If the workers' health and safety are compromised, their productivity may decrease. Therefore, it is vital to prioritise the well-being of employees and provide a safe and healthy work environment (Karuppiah et al., 2020).

The engagement of mining machine operators in the work shows their commitment and concern about their work, which positively reflects on improving safety and productivity. Operators who know about safety and health at work know how to perform their work, how to use protective equipment, and how to preserve health, which leads to a reduction in accidents and injuries. Peters (1989) reveals that lack of job knowledge leads to more dangerous working conditions and contributes to a higher accident rate.

In the light of theoretical analysis, the following hypotheses were developed:

Hypothesis 1. Technical factors have a positive influence on sustainability factors in mining companies

Hypothesis 2. Human factors have a positive influence on sustainability factors in mining companies

Hypothesis 3. Organisational factors have a positive influence on sustainability factors in mining companies

In this study, the hypotheses were developed on the basis of previous research on the impact of safety factors on the sustainable safety activities of mining machinery operators.

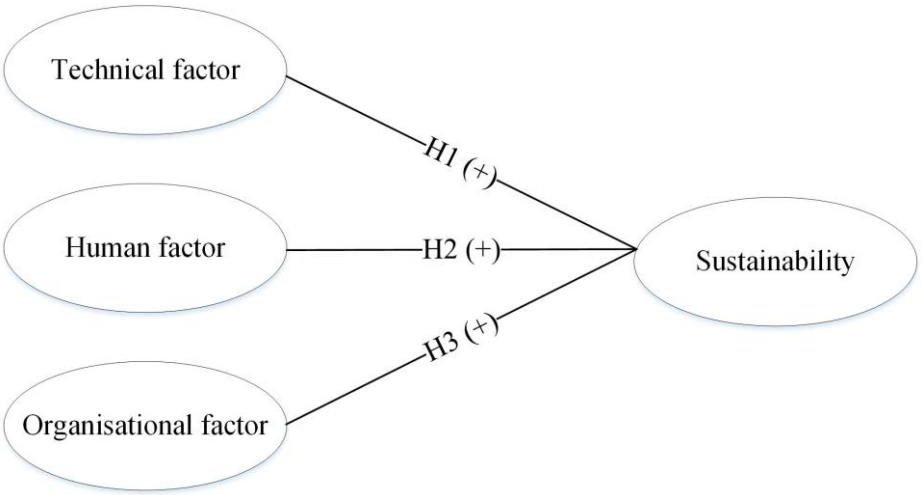

Figure 1. Conceptual model

3. DATA AND METHODOLOGY

A survey methodology was used to analyse management opinions about influential factors of occupational safety and health of mining machinery operators. For this purpose, the technical, human, and organisational factors and sustainability performance were employed using questionnaires that were initially developed in the previous phase under the project "Support Systems for Smart, Ergonomic and Sustainable Mining Machinery Workplaces - SmartMiner" supported by Science Fund of the Republic of Serbia.

The questionnaire was developed by grouping questions based on literature review and existing research in OSHAS. Companies in the mining sector were chosen to evaluate management's opinion on the current state of occupational safety and health for mining machinery operators. Prominent causal and theoretical models of workplace safety were consulted to identify relevant constructs. Most of the data was collected in the field through visits to the management of mining companies and conversations with them, while the other part was collected through an online questionnaire. The data collected was statistically processed using Excel tables and a specialised software package such as SPSS. Responders expressed their attitudes using a Likert five-level scale (1 to 5). Based on the collected data and opinions of the 34 managers, statistical tests were used. The software program SPSS was utilised to evaluate the consistency and correlation within the measurement scale and the impact of the safety factor on the sustainability of the mining companies.

4. RESULTS AND DISCUSSION

The first step in data analysis was descriptive statistics, which were used to describe the observed data and phenomena. Descriptive data on respondents showed that most respondents were male (76.47%). Regarding age, most respondents were between the ages of 26 and 35 (32.35%), as well as between the ages of 36 and 45 (32.35%). For working experience, approximately 44.11% of respondents have between 11 and 15 years or less of experience, which represents very relevant information for the particular topic of the research. Regarding education, the sample reported that most of the respondents, 64.70%, have a university degree, and 32.35% of respondents have a Master’s degree. These facts show that the respondents possess sufficient education levels to comprehend and implement safety measures during their management activities.

Furthermore, a correlation analysis presented the mutual relationship between the observed factors. The results indicate a strong correlation with statistical significance between all considered factors, as depicted in Table 1.

Table 1. Correlation matrix

	Technical factor	Human factor	Organizational factors	Sustainability
Technical factor	1			
Human factor	0.697	1		
Organisational factors	0.790	0.947	1	
Sustainability	0.838	0.798	0.880	1

Cronbach's alpha was used to evaluate the internal consistency of each factor in the scale, Table 2. The obtained results show that all the values of the Cronbach coefficient are over 0.7 (Cronbach, 1951), which fulfils the consistency condition.

Table 2. Cronbach's alpha

	Technical factor	Human factor	Organisational factors	Sustainability
Cronbach Alfa	0.962	0.988	0.981	0.942

Regression analysis was used to test hypotheses and assess the relationship between independent and dependent variables. In this light, it was performed to determine the character and form of the relationship, that is, the regression model between two observed variables in a stochastic relationship (Hair et al., 1998; Ho, 2006). This research considered the impact of technical, human, and organisational factors on sustainability.

Table 3. Model Summary

					Change Statistics				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df1	df2	Sig. F Change
1	0.912a	0.831	0.814	0.317	0.831	49.124	3	30	0.000
a. Predictors: (Constant), Technical factor, Human factor, Organizational factor b. Dependent Variable: Sustainability factor									

Table 3 depicts the results of R Square Change, where 0.831, which means that 83.1% of the variation of the dependent variable "Sustainable factor" is explained by controlled variables such as the Technical, Human, and Organizational factors. Adjusted R Square is a coefficient used in multiple regression analysis to determine the goodness of fit of a model (Harel, 2009). It is introduced because R Square may increase incorrectly when new independent variables are added to the model. In this research, the Adjusted R Square coefficient is 0.814, which indicates that the regression model explains approximately 81.4% of the variance in the dependent variable.

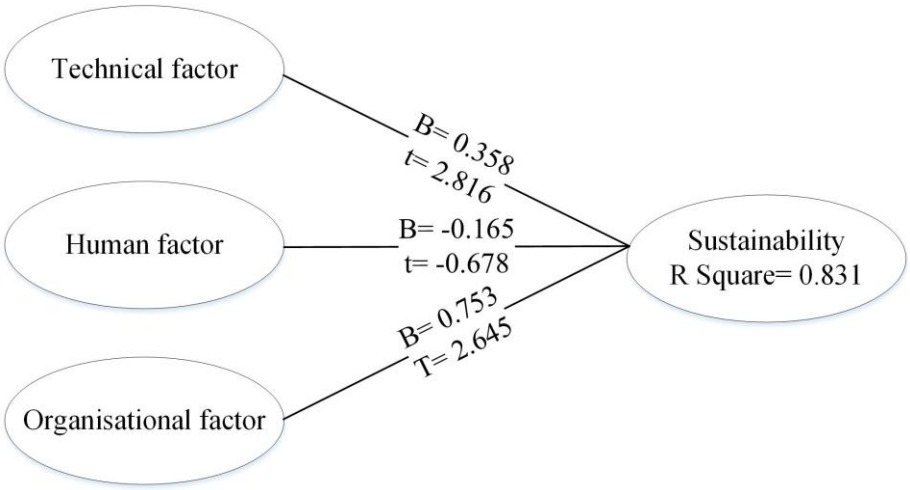

Figure 2. Regression model

The hypotheses were tested using regression analysis, and the results of the path coefficients are depicted in Table 3 and Figure 2. Path analysis depicts that the variables of the technical and organizational factors directly impact the sustainability factor with statistical significance, while the human factor has negative impacts without statistical significance on the sustainability factor.

Table 4. Coefficients' beta regression

	Unstandardized	Coefficients	Standardized Coefficients			Collinearity Statistics	
	B	Std. Error	Beta	T	Sig.	Tolerance	VIF
1 (Constant)	-0.012	0.399		-0.030	0.976		
Technical factor	0.334	0.119	0.358	2.816	.009	0.349	2.865
Human factor	-0.178	0.263	-0.165	-0.678	.503	0.095	9.506
Organizational factor	0.895	0.339	0.753	2.645	.013	0.070	14.387
a. Dependent Variable: Sustainability factor							

Regression analysis was utilised to determine if the influence of technical, human, and organisational factors has an important impact on the sustainability of mining companies. Table 4 presents the VIF value demonstrating the multi-collinearity level. The VIF value indicates the percentage of variation in the independent variable that is not accounted for by other independent variables. If the low VIF values are below 10, they indicate a division or overlapping of the predictive power of the independent variables (Cohen & Cohen, 1983). VIF values greater than 10 cannot be accepted, and that independent variable must be exposed for further analysis (Ho, 2006).

The obtained results of the regression analysis showed that technical and organisational factors have a positive influence on security sustainability, thus confirming hypotheses H1 and

H3. These findings are consistent with the findings of Haas and Yorio (2021), Montibeller and Von Winterfeldt (2015), Gowrisankaran et al. (2015), and Parker et al. (2017). However, a negative relation without statistical significance can be seen between the human factor and the sustainability factor and hypothesis H2 is rejected. These results link with the findings of Wang et al. (2019) and Bayraktar et al. (2023), who indicate that the biggest cause of injuries and accidents is the human factor, which cannot have the sustainable safety activities of mining machinery operators.

In this respect, managers must implement all necessary measures to train, motivate and adapt mining operators to changing workplace conditions to improve the sustainable safety activities of mining machine operators.

5. CONCLUSION

The mining industry plays a significant role in economic development. However, it is also among the most hazardous industries and faces great challenges. The mining industry is characterized by risks and challenges, making safety and health considerations crucial aspects of its sustainability operations. This study aimed to analyze managers' perceptions of workplace safety factors for mining machinery operators. It was necessary to analyse how technical, human, and organisational factors impact the sustainable safety efforts of mining machinery operators in terms of occupational safety and health.

This research's implications are reflected in the identification of key factors that contribute to the effective implementation of security measures and practices. Despite its limitations, the results offer strong empirical support for the proposed theoretical model. These findings provide valuable guidance for researchers and practitioners seeking to enhance safety in the workplace for mining machinery operators. Mining company managers can use these findings as a roadmap to ensure that safety and health standards and procedures for mining machine operators are maintained.

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Original research

HARD HAT DETECTION FOR SAFETY PURPOSES BY USING YOLOV9

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Abstract: Ensuring the safety of workers at workplaces is a crucial task for every company. The usage of personal protective equipment represents the basic form of protection. Hard hats are very useful in protecting head from injuries. However, workers often neglect the importance of wearing safety helmets and do not wear them. Systems for monitoring and detecting unsafe behaviors can be very helpful for maintaining security. For that purpose, this research examines the success of the application of the latest YOLO algorithm for detecting the presence of safety helmets on workers that can be applied in those systems. Two models with different numbers of parameters are trained for this purpose – YOLOv9c and YOLOv9e. The results showed that YOLOv9c model achieved mean average precision of 97.2%, 93%, and 92.9% in training, validation, and testing, respectively, while YOLOv9e reached slightly higher mean average precisions of 97.5% in training, 93.4% in validation and 93.4% in testing.

Keywords: Hard hat detection, deep learning, YOLOv9, safety helmet detection.

1. INTRODUCTION

The safety of workers at the workplace is important not only to workers but also to organizational leaders and policymakers. Worker injuries can be devastating to workers and their families and they cause significant financial costs for organizations (McGonagle & Kath, 2010). One way to minimize exposure to danger that threatens to cause workplace injuries is to use personal protective equipment (PPE). Hard hats are engineered to endure impact and prevent penetration from objects, along with shielding against electrical dangers. When worn correctly by workers, a reduction in fall-related fatalities can be expected, as well as a notable decrease in injuries caused by slips, trips, and being struck by falling objects (Shrestha et al., 2015). Shrestha et al. (2015) also stated in their work the result of the research which showed that 47.3% of fatally injured workers either had not used PPE or had not used it properly. It is clear that systems created to monitor workers and their usage of PPE can help to a large extent in maintaining workplace safety and preventing injuries. Those systems are often based on the usage of deep neural networks that can detect objects in real time with great accuracy. However,

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researchers are always trying to improve those systems by using different deep learning algorithms, upgrading monitoring equipment, etc.

This paper deals with the detection of safety helmets based on images of construction workers during their work. For detection, YOLOv9 deep learning network is used for the first time for this purpose. Keeping the same training parameters, two different YOLOv9 models are trained and a comparison is made.

2. LITERATURE REVIEW

The system proposed in the paper by Shrestha et al. (2015) introduces a construction site monitoring system aimed at enhancing safety practices within organizations. This system integrates closed-circuit television cameras deployed across the construction site, interconnected with a central server, typically hosted on an office computer. The captured video data undergoes analysis, and upon detection of unsafe behavior, alerts are generated via various communication channels such as SMS messages, notifications on other computers, or through speakers. The detection process within the system employs two primary methods - face detection and hard hat detection. Initially, the system conducts face detection to identify individuals within the monitored area. Subsequently, it assesses whether the detected individuals are wearing protective hard hats. Notably, the hard hat detection process is initiated only upon successful face detection. While the proposed system offers a relatively straightforward implementation and is cost-effective, it acknowledges limitations in its detection methodology. Specifically, the reliance on face detection may result in instances where individuals are not properly identified due to occlusions or other environmental factors common in construction sites.

To overcome the mentioned limitation, researchers tried to use You Only Look Once (YOLO) algorithm for detection. It has the ability to process images very fast while containing a high accuracy rate. Wen et al. (2020) conducted a comparative study in which they evaluated an improved YOLOv3 network against YOLOv2 and the standard YOLOv3 for safety helmet detection. Their findings revealed that the improved YOLOv3 model attained a precision of 90.7%, surpassing precisions achieved by YOLOv2 and the conventional YOLOv3. Benyang et al. (2020) created an improved approach built upon the foundation of YOLOv4 for the identical task, achieving a mean Average Precision (mAP) value of 99.89%. This triumphs over the mAP values of both YOLOv3 and the conventional YOLOv4 model. Despite showing a lower mAP value when compared to Faster Region - Convolutional Neural Network, the proposed model demonstrated a substantially superior detection speed which is 75 times faster than the aforementioned alternative. Paper (Kisaezehra et al., 2023) offers a deep learning strategy for monitoring worker's hard hats in real-time using five different YOLOv5 models – YOLOv5n, YOLOv5s, YOLOv5m, YOLOv5l and YOLOv5x. YOLOv5x network achieved the highest value of mAP, 95.8%, while YOLOv5n had the fastest detection speed of 70.4 frames per second. It can be said that these results were expected because YOLOv5x model is the largest, that is, it has the greatest number of parameters, while YOLOv5n is the smallest and, therefore, the fastest. YOLOv5 also overcame the performances of YOLOv6 with a mAP value of 75.7% in research conducted by Ludwika and Rifai (2024). The research focused on using YOLO models to detect seven different PPE objects and to ascertain whether each item was correctly utilized. An improved model based on YOLOv7 model is developed for detecting helmets in six different categories that include helmet, head with helmet, person with helmet, head, person no helmet, and face category. The improved model achieved slightly better results than all standard YOLOv7 models, achieving mAP value of 92.6% (Chen et al., 2023). Sometimes, mAP value is influenced not only by the model of neural network but also by the

dataset that is used. An example of this statement can be found in (Chen & Xie, 2023). That research compared an improved YOLOv7 model with twelve other deep learning models applied to three different datasets for helmet detection. Lin (2024) developed improved YOLOv8 model, that has less parameters than YOLOv8n model, which is the smallest model of YOLOv8 networks. It achieved the highest mAP of 94.36% which is even higher than mAP value achieved by YOLOv8x, which is the second-largest YOLOv8 model.

3. DATASET

The dataset utilized for training and evaluating deep learning models was developed by Aydin and Bulut (2023) and it is available online. It comprises 23 637 distinct images depicting individuals wearing or not wearing safety helmets and vests. Additionally, there is a smaller subset of images exclusively featuring safety vests or hard hats. Each image within the dataset is resized to dimensions of 640 x 640 pixels and comes pre-labeled. Furthermore, the dataset is organized into separate subsets for training, testing, and validation. The training subset encompasses 78% of all images, while the test and validation subsets account for 11% of the total image count each. Random examples from the dataset are depicted in Figure 1.

Figure 1. Random samples of images from the dataset (Aydin & Bulut, 2023)

Even if there are three different classes – helmet, head, and vest, this research takes into consideration only two cases when individuals wear hard hats and when they do not, so vest class is neglected in further study. Figure 2 presents the number of instances for each class in every subset.

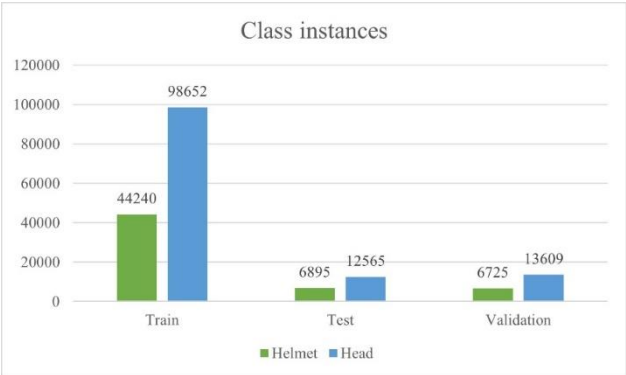

Figure 2. The number of class instances in all subsets

4. YOLOv9 DETECTION MODEL

YOLOv9 is a deep learning detection model developed to overcome the problem of information lost during the feedforward process. It combines the Programmable Gradient Information (PGI) concept and Generalized Efficient Layer Aggregation Network (GELAN), both created by Wang et al. (2024., preprint). The design of YOLOv9 model is based on the Information Bottleneck Principe and Reversible Functions.

Information Bottleneck Principe suggests that during the transformation of data through layers in neural networks information loss can be caused, as it is shown in Equation 1.

$$I(X,X) \geq I\big(X, f_\theta(X)\big) \geq I\left(X, g_\phi\big(f_{\theta(X)}\big)\right), \tag{1}$$

where I indicates mutual information, f, and g represent transformation functions and θ and ϕ represent parameters of transformation functions. In deep neural networks, functions $f_\theta(\cdot)$, and $g_\phi(\cdot)$ are the operations of two sequential layers. It is clear that increasing the number of layers in neural networks increases the probability that the original data will be lost. This means that using incomplete information in training of network can result in unreliable gradients and poor convergence. This disadvantage can be solved by using reversible functions. The reversible function, v, is an inverse transformation function of function r, as shown in Equation 2.

$$X = v_\zeta\left(r_\psi(X)\right), \tag{2}$$

where ζ and ψ are parameters of functions v and r, respectively. Equation 3 shows that if data X is converted by reversible function, then it will not come to the information lost.

$$I(X,X) = I\left(X, r_\psi(X)\right) = I\left(X, v_\zeta\left(r_\psi(X)\right)\right), \tag{3}$$

If network's transformation function includes reversible functions, then more dependable gradients can be obtained for updating the model. However, the repeated passing of original data through subsequent layers in deep learning architectures may lead to effective convergence but for difficult problems, it makes it harder to find simple mapping functions to map data to target. This especially affects the performance of lightweight models because they are under-parameterized when faced with a large amount of raw data.

PGI is a method that is developed to solve analyzed problems and is the first component of YOLOv9. It consists of three components – main branch, auxiliary reversible branch, and multi-level auxiliary information. PGI has only main branch for inference process which means that it does not require any additional computational costs. Next, auxiliary reversible branch serves to generate dependable gradients and update parameters of neural network. It can give reliable gradient information in learning process as main branch deep features might lose significant information due to information bottleneck. This gradient information guides parameter updates to help extract accurate and crucial information, thereby enabling the main branch to obtain features that are better suited for the target task. Nevertheless, PGI method does not compel the main branch to keep all original information but rather enhances it by generating valuable gradients through the auxiliary supervision mechanism. Also, the auxiliary reversible branch can be eliminated during the inference phase, so the original network's inference capabilities can remain intact. Finally, Multi-level auxiliary information has the task

of combining gradient information by inserting integration network between feature pyramid layers of main and auxiliary supervision branch. The gathered information contains all target objects and it is forwarded to the main branch for updating parameters. The point is to mitigate the domination of specific object information to main branch's feature pyramid hierarchy. This technique is useful for making more accurate predictions for objects that have different sizes.

The second component of YOLOv9 model is GELAN. It is a neural network architecture created by combining two neural networks – Cross Stage Partial Network (CSPNet) and Efficient Layer Aggregation Network (ELAN). It considers lightweight design, accuracy, and inference speed. The main idea behind GELAN is to use ELAN architecture, which only uses a composition of convolutional layers, but to generalize it by using any computational blocks, which is characteristically for CSPNet. Figure 3 shows the PGI method and GELAN architecture, which represent the base of YOLOv9.

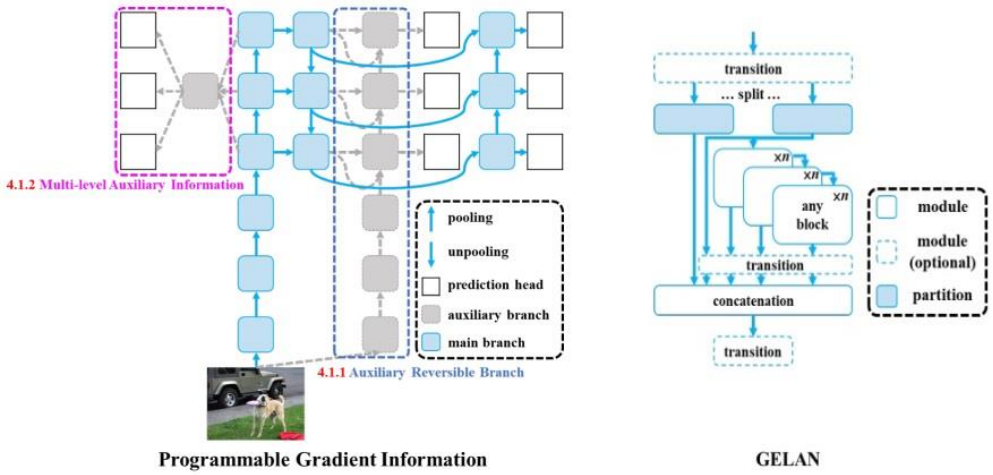

Figure 3. PGI and GELAN, (Wang et al., 2024, preprint)

5. TRAINING PARAMETERS

For the experiment, the image size is kept as the default size for YOLOv9 models. Two models are trained – YOLOv9c and YOLOv9e, with the same training parameters. As data augmentation methods translating, scaling, left-right flipping, mosaic, mixing up, and copy-pasting segments of image are used. Some of the parameters are given in Table 1.

Table 1. Training parameters

Parameter	Value
Optimizer	Stochastic Gradient Descent
Number of epochs	100
Batch size	8
Learning rate	0.01
Momentum	0.937
Weight decay	0.0005
Translate probability	0.1
Image scale	0.9
Flip left-right probability	0.5
Mosaic probability	1.0
Mix up probability	0.15
Segment copy-paste probability	0.3

6. RESULTS AND DISCUSSION

6.1. Evaluation criteria

One of four cases can be a result of each detection that describes if our model detected and classified an object correctly. Those cases are:

- True positive (TP), the case when the object is correctly detected
- False positive (FP), in the case when the detected bounding box is misplaced or in the case of incorrect object detection
- False negative (FN) when the object in the image is not detected
- True negative (when instances in pictures are not detected as objects, this case is not taken into consideration for object detection problems, because there is an infinite number of instances in the pictures that are not detected as objects)

Sums of all true positive, false positive, and false negative cases allow for calculating network's performance measures. In object detection, precision, recall, mAP, and F1 score are usually considered as performance measures.

Precision is the ability of a model to identify only objects that are relevant, in other words, the percentage of correct positive predictions (Padilla et al., 2020). It can be calculated as:

$$\text{Precision}_c = \frac{\text{TP}_c}{\text{TP}_c + \text{FP}_c}, \tag{4}$$

where c represents object's class. Recall represents the model's ability to find all relevant classes (Padilla et al., 2020). It can be represented via following equation:

$$\text{Recall}_c = \frac{\text{TP}_c}{\text{TP}_c + \text{FN}_c}, \tag{5}$$

F1 score is performance measure that takes into account precision and recall value, in the form as in the Equation 6.

$$F1_c = \frac{2 \cdot \text{Precision}_c \cdot Recall_c}{\text{Precision}_c + Recall_c}. \tag{6}$$

AP refers to the average value of all precisions obtained under all possible recall rates. The mAP is the average of the AP value in all categories (Jin et al., 2021), and it can be calculated as:

$$mAP = \frac{1}{N} \sum_{c=1}^{N} AP_c , \tag{7}$$

where *N* is the number of classes, *c*.

6.2. Obtained results

Results obtained after a hundred epochs on train, test, and valuation data for both models are shown in Table 2.

Table 2. Values of performance measures

	YOLOv9c			YOLOv9e		
	Train	Validation	Test	Train	Validation	Test
$Precision_{helmet}$	94.3%	93.2%	93.6%	94.6%	93.5%	93.6%
$Precision_{head}$	94.7%	91%	91.3%	95%	91.1%	91.2%
Overall Precision	94.5%	92.1%	92.5%	94.8%	92.3%	92.4%
$Recall_{helmet}$	94.8%	89.3%	88.1%	95.4%	89.3%	88.7%
$Recall_{head}$	93%	91%	91.9%	93.7%	91.8%	93.3%
Overall Recall	93.9%	90.1%	90%	94.6%	90.5%	91%
$F1_{helmet}$	94.5%	91.2%	90.8%	95%	91.4%	91.1%
$F1_{head}$	93.8%	91%	91.6%	94.3%	91.4%	92.2%
Overall F1	94.2%	91.1%	91.2%	94.7%	91.4%	91.7%
mAP	97.2%	93%	92.9%	97.5%	93.4%	93.4%

From Table 2 is clear that YOLOv9e, a larger network, that is, a network with more parameters achieved slightly better performance results. Even if YOLOv9c achieved the same or higher precision values in the test category, recall has smaller values. That means this model is capable of correct detection but there are more FN cases, cases when instances are presented in the image, but not recognized. However, as YOLOv9c has less number of parameters, learning is faster, as well as the detection process.

Figure 4. Examples of detection on the test set of YOLOv9c – a) examples of correct detection b) examples of incorrect detection

Figure 4 represents YOLOv9c detection results on the test set, which has not taken part in the training process, meaning that this data is unknown for the trained model. Part a) shows some examples of correct detection, while part b) shows some mistakes made by using YOLOv9c model. It should be pointed out that, as the results show, there are a lot more cases of correct detection, but for the sake of comparison between proposed models, more examples of mistakes are given in this paper. As can be seen, the model can neglect the presence of heads and helmets, not recognizing them which can cause problems, especially in the case of not

detecting heads. On the other hand, sometimes a mistake is caused by detecting the wrong object as the left top image of the b) part in Figure 4 shows, when glove is recognized as helmet. Figure 5 shows the detection results of YOLOv9e model, for the same image data.

Figure 5. Examples of detection on the test set of YOLOv9e – a) examples of correct detection b) examples of incorrect detection

YOLOv9e model also correctly detected heads and helmets on the data showed in Figure 5, part a). However, when parts b) of Figures 4 and 5 are compared, it can be noted that YOLOv9e model did not make mistakes on the two left images, as YOLOv9c did. Of course, some mistakes are made, as shown in the right images of part b) in Figure 5, but they are the same that YOLOv9c made.

7. CONCLUSION

This study acknowledges the significance of employing deep learning models to enhance workplace safety for workers. Initially, it examines the deployment of earlier YOLO algorithms for identifying PSE, based on published researches. In continuation, it elucidates the advancements and innovations achieved by the YOLOv9 algorithm, representing the latest iteration of YOLO algorithm. Further, two large models, YOLOv9c and YOLOv9e, are trained for detecting the utilization of safety helmets by workers at workplaces, the first time for the mentioned purpose.

Results showed that both models achieve high value of mAP, but as it was expected, larger model, YOLOv9e, showed as a more precise model, achieving mAP of 97.5% during training, 93.4% during validation, and 93.4% during testing phases. It was observed that certain errors made by YOLOv9c could be mitigated by employing YOLOv9e. However, training of YOLOv9e is computationally demanding, so the training is more time-consuming and the detection process is slower.

In order to improve performances of models, it is recommended to use different hyperparameters, optimization, and regularization techniques. Further research may refer to

training lighter models of YOLOv9, or implementing trained models on real time systems, as they are reliable and easy to use.

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Original research

A HYBRID RELIABILITY - FMEA METHODOLOGY IN RISK ASSESSMENT OF A BELT CONVEYOR SYSTEM

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Abstract: An appropriate maintenance strategy can maximize a machine's capacity and economic lifetime and also produce yearly savings of several million euros. That being said, a risk assessment approach can help companies identify the systemic bottlenecks that are interfering with their development and cut a large portion of their profit each year. This paper presents a hybrid reliability-Failure Mode and Effects Analysis (FMEA) methodology to assess the risk associated with belt conveyor systems, particularly in open-pit mining environments. By integrating severity, occurrence, and detection indicators, a 3D risk assessment matrix was developed. Using data from conveyor system maintenance, including downtime and failure occurrences, chi-square tests to analyze system reliability and mean downtime were applied. The methodology allows for a nuanced understanding of the frequency and severity of failures, enabling more informed decision-making about maintenance strategies. The paper highlights the economic implications of system failures and the potential for substantial financial savings through optimized maintenance planning.

Keywords: risk, reliability, mining, belt conveyor.

1. INTRODUCTION

During the 1970s, an energy crisis affected the whole Western world. Implementing solutions with lower labor and energy requirements has become a fundamental goal for companies in order to stay competitive in the market. Problems in the mining industry were no different, as transportation of ores needed to be done with minimum energy and costs. Although it had been invented almost 100 years earlier, a belt conveyor finally found its spot under the sun at the time, especially in bulk material extraction such as coal. Among its low operating costs, other advantages such as safety of operation, reliability, versatility, and a broad range of capacities have led it to become a dominant transportation solution for a wide variety of engineering problems (CEMA, 2014).

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Nowadays, belt conveyors present a reliable provider of continuous material flow between operations without loss of time for loading and unloading or empty return trips (CEMA, 2014). However, factors such as aging from long-term operation, heavy or impact loads, complex operating environments and long transport distances may generate undesirable phenomena, e.g., wear or puncture. Each one of those can develop into long-range tears, forcing an unexpected downtime. Material delays may result in huge financial losses for companies in the mining industry. Therefore, the maximum effort should be put into its prevention (Guo et al., 2022).

In Serbia, coal was, is, and will be the most significant source of energy, with 85% participation in the structure of overall primary energy reserves (Pavlovic et al., 2011). Hence, the proper functioning of systems for their exploitation can be presented as not only a primary goal for the mining companies but also as a matter of highest interest at the state level. The conveyor belt, as a fundamental part of a belt conveyor system, presents *"the main artery for coal mine production and transportation"* (Hou et al., 2024). The idea of mitigating risk in such a system seems reasonable if the ultimate goal is to minimize overall costs. A methodology suggested by Spasojević-Brkić et al. (2023) will be applied in an attempt to deal with the problem adequately. At first, similar previous research was discussed. Eventually, the results will be put into a defined risk assessment framework.

2. LITERATURE REVIEW

Heavy machinery, including rubber belt conveyors, bucket-wheel excavators, dredges, and dumpers, is commonly used in modern open-pit mines for tasks such as overburden removal, transport, crushing, and loading (Ignjatović et al., 2018). Thus, much research was done to determine heavy machinery reliability and the consequences of improper maintenance. Bugarić et al. (2014) proposed a methodology used to determine the rubber belt conveyor's reliability function, operating on machines (bucket-wheel excavator, belt wagon, spreader) that remove overburden on the Tamnava – East Field open-pit mine. The research was based on the fact that the mean operating time until failure may be represented by the composition of an exponential distribution (sudden failures) and a normal distribution (gradual failure). Štatkić et al. (2019) also calculated the mean time to failure (MTTF) in order to analytically assess the reliability of a single-motor drive that powers a rubber conveyor belt at the Drmno open-pit mine. Analysis from a study by Li et al. (2019) generated a Weibull three-parameter distribution model, which has shown that the probability of belt conveyor failure or breakdown can rise to almost 25% during continuous operation for 24 hours.

To prevent failures and increase reliability, we view such systems from a broader perspective and consider non-technical factors. Therefore, risk management is important. Kecojevic et al. (2008) analyzed the risk associated with fatal incidents on belt conveyors in the U.S. mining industry. Risks were identified and quantified via the Preliminary Hazard Assessment (PHA) method, and their levels were then developed using a pre-established risk matrix that ranks risks according to probability and severity. On the other hand, two studies by different authors (Burduk, 2012; Özfırat et al., 2022) applied Failure Modes and Effects Analysis (FMEA) to a belt conveyor system with the goal of identifying and ranking risks according to their RPN (Risk Priority Number). Burduk (2012) used linguistic variables to reveal risk factor cause-and-effect relationships and reduce their impact on production systems. Additionally, Özfırat et al. (2022) have done Event Tree Analysis (ETA) for each previously identified risk to display and decrease their severity degrees. A study by Moghrani et al. (2023) took a step further, proposing a RPI-MCDM-based FMEA evaluation model that classifies failure modes of systems and machines in order to enhance failure modes in belt conveyor

systems and the mining industry in general. Although numerous authors analyzed risk inside a mining environment, most of the research was done from a safety perspective, where potential hazards were perceived as the main consequence. This study aims to model risk from an economic perspective, placing generated costs as the main side effect of an unplanned downtime.

3. METHODOLOGY

Based on the construction characteristics of belt conveyors and the number of existing data points for analysis, the observed belt conveyor system was divided into three sub-systems. The primary sample of the conveyor's performance consisted of recorded downtimes and times between failures. Recorded failures were separated into three different categories: failure of mechanical parts, failure of electrical parts, and other failures. Firstly, a chi-square test will be used to determine which theoretical statistical distribution best fits the data regarding downtimes and intervals between failures. The next stage is the determination of the system's reliability/unreliability functions. The method of their calculation will be selected based on the results of the statistical testing. In other words, the functions can be found analytically if the data can be represented by an exponential theoretical distribution for all types of failures and sub-systems. Otherwise, another way of proving their determination must be found. Eventually, the overall system's risk will be evaluated inside a three-dimensional risk assessment model.

4. RESULTS AND DISCUSSION

4.1. Statistical testing of the data

As has already been said, the main conveyor system (B.C.-S#0) has been divided into three different sub-systems (B.C.-S.S#1, B.C.-S.S#2, and B.C.-S.S#3). The times between failures and downtimes were perceived separately for mechanical and electrical failures in each sub-system. Other failures that were happening inside all of the sub-systems were summarized into one sample, perceiving it as a fictional additional sub-system (B.C.-S). Within all sub-systems, the data could be approximated with the exponential theoretical distribution (Figures 1-4) with a relevance threshold of $\alpha = 0.01$.

Table 1 shows the parameters of each distribution. Parameters of the TBF distribution present the failure intensity (λ) of each failure type. On the other hand, revealing the DT distribution parameter allows generating the maintenance intensity (μ).

Table 1. Results of application the $\chi 2$ – test

Object	Failure type	No. of failures	Distribution of TBF		Distribution of DT	
			Type	Parameter λ	Type	Parameter μ
B.C.-S.S#1	Mechanical	226	E1	0.003190810	E1	0.049033847
	Electrical	15	E1	0.004083211	E1	0.023637302
B.C.-S.S#2	Mechanical	202	E1	0.003574741	E1	0.054267622
	Electrical	90	E1	0.003387967	E1	0.026733403
B.C.-S.S#3	Mechanical	394	E1	0.004548413	E1	0.037638440
	Electrical	249	E1	0.005242600	E1	0.032062975
B.C.-S	Other	70	E1	0.005482600	E1	0.023120329

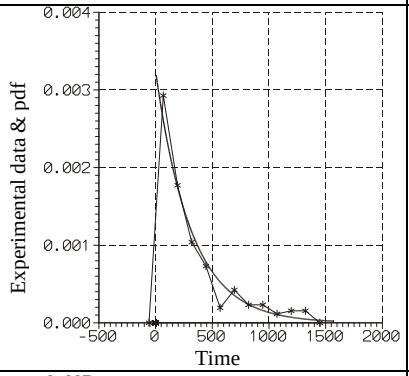
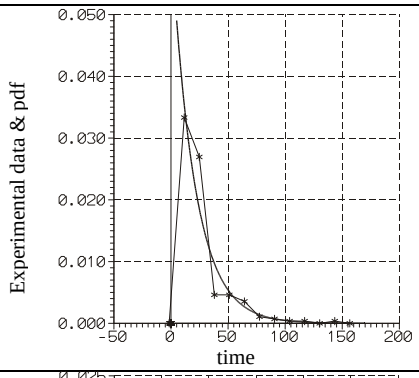
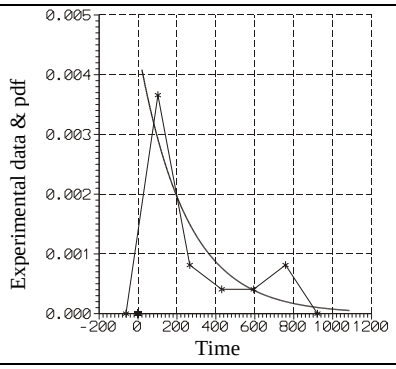
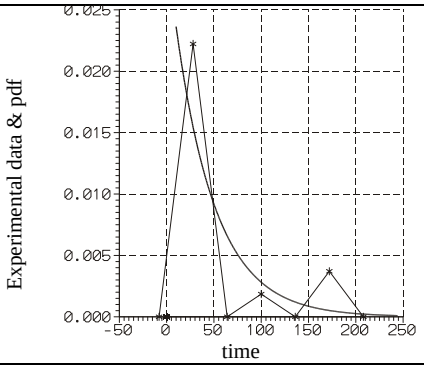
Object	Failure type	Distribution of TBF	Distribution of DT
B.C.-S.S#1	Mechanical		
	Electrical		

Figure 1. Distribution of TBF and DT for B.C.-S.S#1

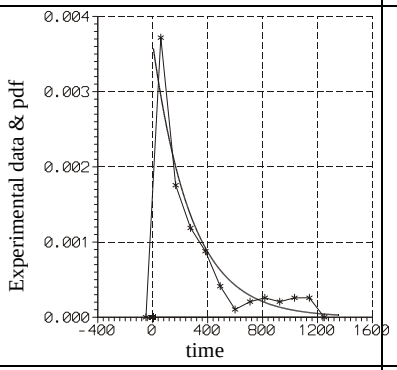
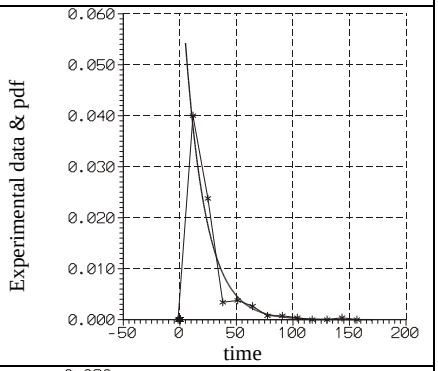
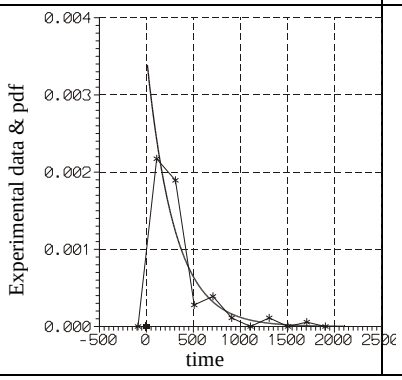
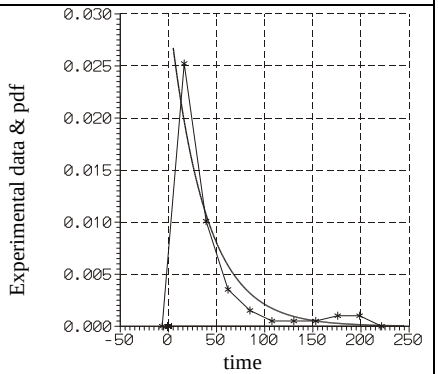
Object	Failure type	Distribution of TBF	Distribution of DT
B.C.-S.S#2	Mechanical		
	Electrical		

Figure 2. Distribution of TBF and DT for B.C.-S.S#2

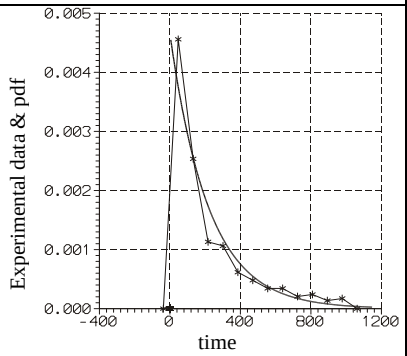
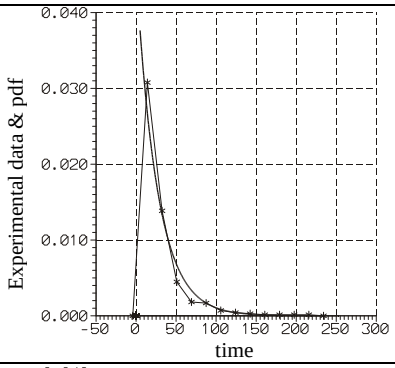
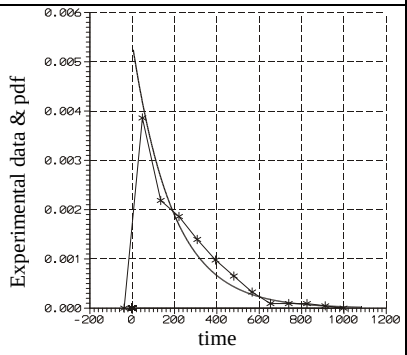
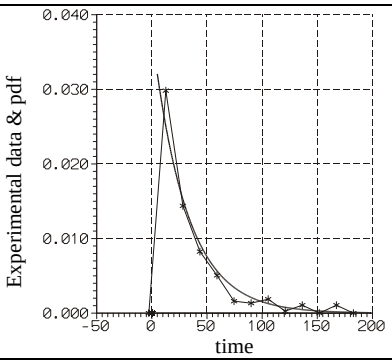
Object	Failure type	Distribution of TBF	Distribution of DT
B.C.-S.S#3	Mechanical		
	Electrical		

Figure 3. Distribution of TBF and DT for B.C.-S.S#3

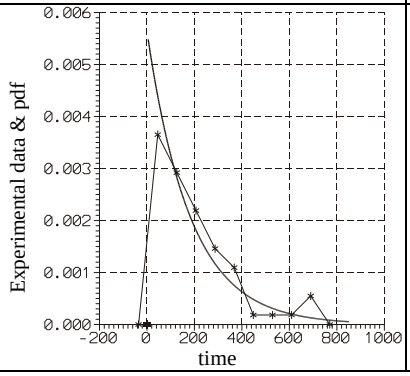
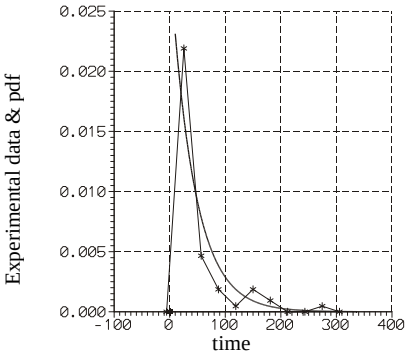
Object	Failure type	Distribution of TBF	Distribution of DT
B.C.-S.	Other		

Figure 4. Distribution of TBF and DT for other failures

4.2. Reliability analysis

As it has been proven that the samples can be affiliated with the exponential theoretical distribution, the belt conveyor system's reliability will be calculated analytically as the reliability of a system with serially connected elements, where each sub-system presents an element from a theory standpoint. In other words, Equation (1) can be used for its calculation:

$$R_{BCS}(t) = R_1(t) \cdot R_2(t) \cdot \ldots \cdot R_7(t) = e^{-\lambda_1 \cdot t} \cdot e^{-\lambda_2 \cdot t} + \cdots + e^{-\lambda_7 \cdot t}$$
$$R_{BCS}(t) = e^{-(\lambda_1+\lambda_2+\lambda_3+\lambda_4+\lambda_5+\lambda_6+\lambda_7)\cdot t} = e^{-\lambda_{BCS} \cdot t} = e^{-0.029510342 \cdot t} \quad (1)$$

Where:

λ_1 – mechanical failure intensity for B.C.-S.S#1,
λ_2 – electrical failure intensity for B.C.-S.S#1,
λ_3 – mechanical failure intensity for B.C.-S.S#2,
λ_4 – electrical failure intensity for B.C.-S.S#2,
λ_5 – mechanical failure intensity for B.C.-S.S#3,
λ_6 – electrical failure intensity for B.C.-S.S#3,
λ_7 – other failure intensity (B.C.-S), and
$\lambda_{BCS}\ [1/\text{h}]$ – failure intensity of a whole system.

Conversely, the unreliability of a system presents the probability of its failure in a given period of time and it can be determined by the following Equation (2):

$$F_{BCS}(t) = 1 - e^{-\lambda_{BSC} \cdot t} = 1 - e^{-0.029510342 \cdot t} \tag{2}$$

Figure 5 reveals a graphical representation of the change in the conveyor's reliability and unreliability over a period of one week or 7 days (168 h).

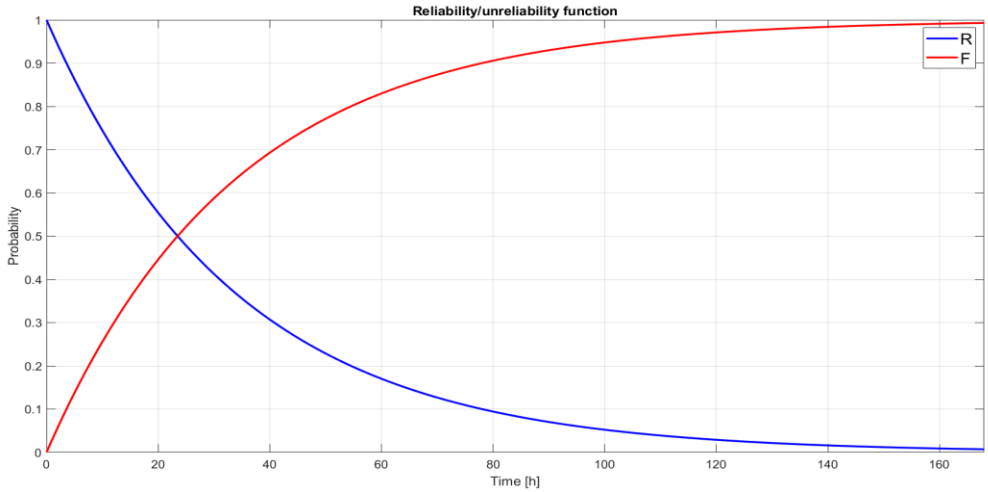


Figure 5. The change of system's reliability and unreliability in a period of one week

In order to differentiate the impact each type of failure has on a system, three mean downtimes (MDT) will be calculated, each based on the type of failure that caused it. MDT due to mechanical failures (MDT_M) can be calculated as an expected value of downtimes generated from each distribution:

$$MDT_M = \left(\frac{226}{822} \cdot MDT_{M1} + \frac{202}{822} \cdot MDT_{M2} + \frac{394}{822} \cdot MDT_{M3}\right) = 22.87 \text{ min} \approx 0.38 \text{ h} \tag{3}$$

Accordingly, mean downtime due to electrical failures (MDT_E) will be calculated as:

$$MDT_E = \left(\frac{15}{354} \cdot MDT_{E1} + \frac{90}{354} \cdot MDT_{M2} + \frac{249}{354} \cdot MDT_{E3}\right) = 33.24 \text{ min} \approx 0.55 \text{ h} \tag{4}$$

When it comes to other failures, mean downtime is calculated using equation 5:

$$MDT_O = \frac{1}{\mu_7} = \frac{1}{0.023120329} = 43.25 \text{ min} \approx 0.72 \text{ h} \tag{5}$$

4.3. Risk assessment model

One of the most approved tools for identifying and eliminating potential failures to enhance the reliability and safety of complex technical systems is the Failure Modes and Effects Analysis (FMEA) method (Liu et al., 2013). The international standard ISO/IEC 31010 officially shaped the method's definitions and principles. FMEA uses the risk performance number (RPN) to determine the risk level (Djenadic et al., 2022).

Equation 7 gives the total RPN for all failures, which ultimately indicates the total risk level in a belt conveyor system. The risk performance comprises three component indicators that accurately portray risk as a whole. On a 5-point rating system, each component indicator can be evaluated.

$$RPN = S \cdot O \cdot D \tag{6}$$

The severity of the consequences (*S*) is calculated in order to precisely determine the intensity of the incident. This metric aims to quantify the financial impact that the current delay has on a company. The severity of the failure is assessed using the total costs (*TC*) incurred as a result of the belt conveyor malfunction, among which lost revenue and repair costs are the most prevalent ones. A study conducted by Bugaric et al. (2012) found that the company loses 9232.33 EUR for every hour of material delay, i.e., the malfunction costs of the overburden excavation system per hour are equal to *ATC*=9232.33 [EUR/h]. Thus, Table 2 presents the defined rankings of the event's severity.

Table 2. Severity of consequences evaluation

Criterion	Severity of consequences	Rank
$TC \leq 1000$ [EUR]	Very Low	1
$1000 < TC \leq 3000$ [EUR]	Low	2
$3000 < TC \leq 5000$ [EUR]	Medium	3
$5000 < TC \leq 10000$ [EUR]	High	4
$TC > 10000$ [EUR]	Very High	5

The severity ranks of each type of failure are given inside Table 3 and evaluated by calculating the average total cost per failure ($ATCF = ATC \cdot MDT$).

Table 3. Evaluated ranks for each type of failure

Type of failure	*ATCF* [EUR]	Severity of consequences	Evaluated Rank
Mechanical	3519.10	Medium	3
Electrical	5114.78	High	4
Other	6655.28	High	4

The second partial indicator is the probability of occurrence (*O*). It presents a quantified parameter that shows the level of uncertainty or likelihood that an unforeseen delay or failure could happen. Table 4 depicts the evaluation procedure based on the system's unreliability. Table 5 examines the failure function in four distinct scenarios, highlighting the increasing significance of this indicator over time.

Table 4. Probability of occurrence evaluation

Criterion	Probability of occurrence	Rank
$F(t) \leq 0.2$	Very Low	1
$0.2 < F(t) \leq 0.4$	Low	2
$0.4 < F(t) \leq 0.6$	Medium	3
$0.6 < F(t) \leq 0.8$	High	4
$F(t) > 0.8$	Very High	5

Table 5. Four scenarios that illustrate how second risk dimension (O) changes through time

Scenario	Operating time	Probability of failure	Rank
I	1 work shift = 8 h	$F(8) = 0.2103$	2
II	1 day = 24 h	$F(24) = 0.5075$	3
III	2 days = 48 h	$F(48) = 0.7574$	4
IV	3 days = 72 h	$F(72) = 0.8805$	5

The third partial indicator, detection rate (D), quantifies the impact of a failure type based on the simplicity of determining its cause when a failure occurs. Additionally, it weighs the potential problems with discovering a specific failure mode through controls and inspections (Wang et al., 2012). Table 6 provides the ranking of the event detection rate based on the type of failure.

Table 6. Detection rate indicator evaluation

Criterion	Detection rate	Rank
/	Very High	1
Failure type is mechanical.	High	2
Failure type is due to other influences.	Medium	3
Failure type is due to power/electricity.	Low	4
/	Very Low	5

Table 7 presents a thorough risk classification and recommended actions based on a study by Spasojević Brkić et al. (2023) that has already outlined the guidelines. The individual risks of each failure type are given in the following equations, considering the worst-case scenario when it comes to the probability of occurrence.

$$RPN_M = S \cdot O \cdot D = 3 \cdot 5 \cdot 2 = 30 \quad (7)$$
$$RPN_E = S \cdot O \cdot D = 4 \cdot 5 \cdot 4 = 80 \quad (8)$$
$$RPN_O = S \cdot O \cdot D = 4 \cdot 5 \cdot 3 = 60 \quad (9)$$

Table 7. RPN interpretation

Criterion	Risk level	Suggested actions
$RPN \leq 25$	Very Low	Regular cost analysis once in a year.
$25 < RPN \leq 50$	Low	Cost analysis once in 6 months.
$50 < RPN \leq 75$	Medium	Cost analysis once in 3 months.
$75 < RPN \leq 100$	High	Cost analysis every month.
$RPN > 100$	Very High	Cost analysis as soon as possible.

In summary, the evaluated risks for mechanical and other types of failure are evaluated as “Low” and “Medium”, whereas electrical failures can potentially cause the most problems, being in the category of “High” risk, which indicates that cost analysis should be done every month. Figure 5 displays a graphic representation of the conveyor's highlighted RPNs in a three-dimensional risk assessment matrix. Risk analysis enables perceiving the “critical spots” of the

system and reconsidering the current maintenance strategy. In other words, if the system is generating costs beyond defined boundaries, a change in the maintenance approach is advised. Proper maintenance strategy with adequate diagnostic tools allows the engineer to make a decision on when the moment of preventive belt replacement will be, which drastically reduces the probability of unplanned downtime and potential replacement of the belt with a new one in emergency mode (Błażej et al., 2022).

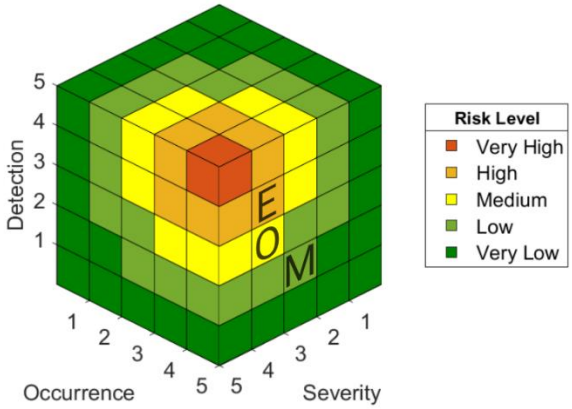


Figure 6. RPNs of a belt conveyor system in a 3D Risk Assessment Matrix
(M – Mechanical, E – Electrical and O – Other type of failure)

5. CONCLUSION

Although years of exploitation increase the overall system's risk level and slowly drag its reliability down, an adequate maintenance strategy can minimize the consequences and generate annual savings of several million euros. That being said, a risk assessment approach can help companies map the spots in the system that represent a barrier to their development by losing them huge amounts of revenue annually. High RPN scores indicate that failure prevention isn't managed properly and that something different must be done from a strategic management point of view. This research's primary limitations are the initial small sample size and the absence of reference risk scores for other heavy machines. Additionally, the financial data, which was the root of the severity indicator formation, could be taken as outdated. Inflation and volatility in the energy market certainly had a significant impact on prices during the previous years. Therefore, besides expanding the present sample, the focus of further research efforts should be on applying the established methodology to the rest of heavy equipment and revising the costs of delays per hour based on the latest financial reports in the mining industry.

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Original research

A RISK EVALUATION OF BULLDOZER DOWNTIMES AND ITS ECONOMIC JUSTIFICATION IN OPEN-PIT MINES

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Abstract: The mining industry has been steadily expanding annually to keep up with the increasing demands. Consequently, used machinery needs to work efficiently, which indicates that unexpected downtimes should be at the minimum possible level. Proper identification and risk evaluation of the potential breakdown is the most important element for efficient equipment maintenance and breakdown prevention. This research has focused on its reliability function determination and analyzed the consequences of downtime and the cost of repairs over a period of one year. Delays on the observed mining machine were classified according to the type of downtime: mechanical, technological, power/electricity, and downtime due to external influences. Input elements for risk assessment were severity of consequence (S), probability of occurrence (O), and failure detectability (D). The method used in this paper is based on the cost of maintenance and the impact of bulldozer breakdowns on reliability in order to maintain profitability and, by reducing the number of unwanted events caused by sudden failure of parts, increase safety during operation. Results show that the monitored bulldozer belongs to the lowest defined risk class, so its use is economically justifiable.

Keywords: risk, reliability, mining, bulldozer, profit.

1. INTRODUCTION

The mining industry, as one of the crucial suppliers of raw materials for global industry, is experiencing steady growth every year to meet demands, since the projections of demand for minerals indicate a rise of 2-3 times until 2050 (Elshkaki et al., 2016; 2018). To meet the demand, high efficiency in the extraction process necessitates continuous use of machinery. According to Bąk and Turek (2023), machine availability has a significant impact on available work time in mines. Frequent stoppages and breakdowns can reduce daily mined volume by

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50% (Bąk & Turek, 2023). With the high rate of accidents, the mining industry can be considered one of the most dangerous, with serious casualties and property losses on a yearly basis (Mahdevari et al., 2014; Miao et al., 2023). To improve the safety level and proper functioning of equipment, a new approach for risk assessment should be used (George & Renjith, 2021; Brkić et al., 2023).

Mining in open pits often involves a great variety of machinery of different sizes and applications. Large equipment is often used for main excavation, loading of material, and transport processes, for example, rotor wheel excavators, dumpers, and conveyers, but these processes are supported by different auxiliary tasks, like site planning, surface cleaning, road maintenance, building of canals and water reservoirs, etc. The machines specialized for those kinds of work are often called auxiliary equipment, and they include loaders, dozers, hydraulic excavators, graders, pipelayers, rollers, trucks, etc. (Ignjatović et al., 2018)

Numerous studies have shown that the availability and reliability of mining auxiliary equipment enable high efficiency in the entire mining process (Gomilanović et al., 2023), and the aim of this paper is to propose a reliable method for risk monitoring and assessment for dozers working in open pit mines so safety and efficiency can be upgraded while minimizing downtimes and breakdowns during the working process. This paper is structured as follows: it starts with an introduction, which is followed by a literature review, and continues with methodology, results and discussion, and conclusion sections.

2. LITERATURE REVIEW

A dozer is a crawler-type tractor with a front blade, and thanks to its capability to efficiently move large quantities of material, it is one of the most common pieces of auxiliary equipment in open pit mines (Jankovic et al., 2019; Munda & Widodo, 2021). On a mine site, it is used for: extending land stuffing, road maintenance, opening mountain roads, and transferring land (Ignjatović et al., 2018; Munda & Widodo, 2021). Because it is widely used equipment, numerous risks are associated with its exploitation. However, research has shown that most of the published papers focus on assessing the health risk for serious injuries to occur (Md-Nor et al., 2008; Rosanti et al., 2022) or downtime cost evaluation (Bhushan et al., 2022; Bugaric et al., 2022). As stated in Spasojević-Brkić et al. (2015), safety and sustainable business success cannot be viewed separately. Proper equipment maintenance can improve overall throughput by up to 7 percent, as the cost of mining vehicle maintenance can contribute to 30–40 percent of total mining costs (Sharma et al., 2022). The most frequent causes of failure, according to the results of the Pareto analysis, from the aspect of failure risk are heating repair, oil change, bulldozer cleaning, screw replacement, tonsil adjustment, filter replacement, part repair, hose replacement, and bearing replacement (Spasojević-Brkić et al., 2022). Bhushan et al. (2022) analyzed the crawler dozer transmission's reliability, availability, and maintainability (RAM) using the Markov method and total productive maintenance (TPM) and found that applying preventive maintenance (PM) can increase the dozer's availability by 9 percent. FMEA and FMECA can effectively evaluate the risk of failure based on quantitative data (Kumar & Kumar, 2016), leading to more efficient equipment maintenance (Jafarpisheh et al., 2020). Tanasijevic et al. (2019) have used a fuzzy-based decision support model for bulldozers' effectiveness evaluation and shown that the experts opinions lead to results comparable to measurements (Tanasijevic et al., 2019). Similarly, Djenadic et al. (2019) used fuzzy theory to provide a conceptual and mathematical model for the bulldozer's availability evaluation based on expert opinion, together with the related analytic hierarchy process (AHP) multi-criteria analysis.

This paper utilizes a method that considers the cost of maintenance and the impact of bulldozer breakdowns on reliability. The goal is to maintain profitability and enhance operational safety by reducing the number of unwanted events caused by sudden part failures.

3. METHODOLOGY

This research's central idea has evolved into a four-phase methodology. The primary database, which consists of recorded bulldozer's downtimes over a period of six months, presents the basis for all further analysis. The first step is to examine and categorize the collected data based on the type of downtime. The Pareto diagram will be used for this purpose. In the second phase, a chi-square test will be used to determine the number of failures over a specific time period.

Next, it will be tested for downtime as a random variable using the Kolmogorov-Smirnoff test. The goal of testing is to determine which theoretical statistical distribution best fits the data. The approach of reliability/unreliability function determination in the third phase shall be chosen based on the statistical testing results. To put it another way, if the number of failures in a given period of time can be represented by the Poisson theoretical distribution, referring functions can be calculated analytically. Whereas, the downtime distribution will define the equation that generates the mean downtime, which is needed in the last phase of the study. Finally, the overall bulldozer's risk will be evaluated using a three-dimensional risk assessment model.

4. RESULTS AND DISCUSSION

4.1. Data analysis and classification

A Pareto chart was created with the goal of representing the distribution of failure types and identifying which ones are most significant (Figure 1). Delays in the observed auxiliary machinery were categorized according to the type of downtime: mechanical downtime, technological downtime, power/electricity downtime, downtime due to external influences, misuse and organizational downtime.

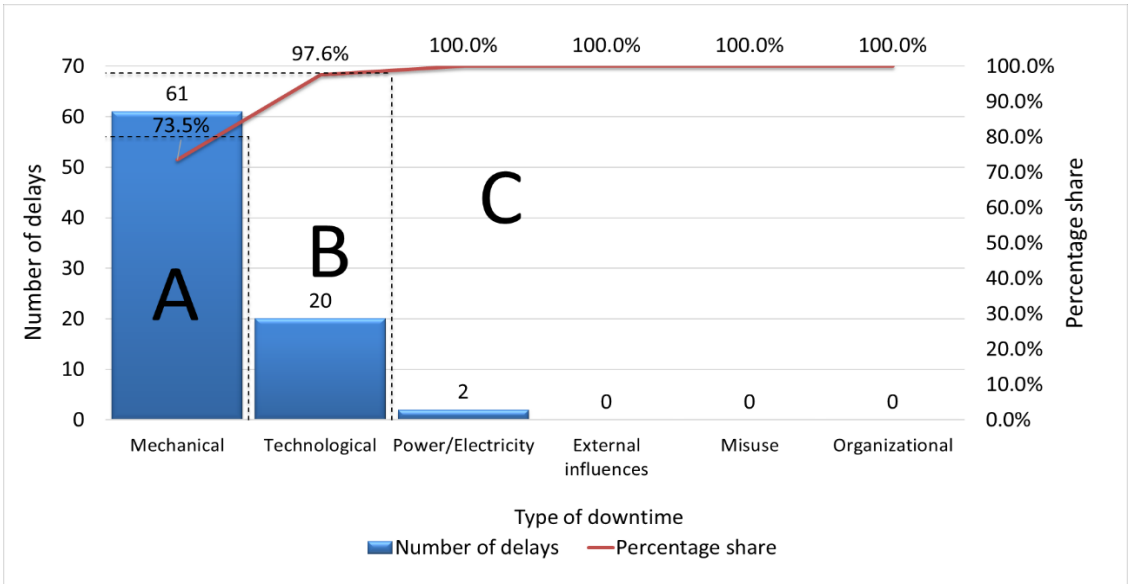

Figure 1. Pareto chart of downtime types

As it can be seen in Figure 1, mechanical and technological downtimes represent an almost complete majority, with 97.6% of the whole sample (zones A and B). Thus, from a maintenance and risk management point of view, the two types should be the most crucial factors.

4.2. Statistical testing of the data

Utilizing the chi-square test, it was determined that the number of failures in a given time was associated with the Poisson theoretical distribution characterized by the rate parameter λ_1= 0.360827375 with the relevance threshold of $\alpha = 0.01$ (Figure 2). The Poisson distribution can be described by its probability density function, which is given in Equation 1:

$$f(x) = P(X = x) = \frac{(\lambda \cdot t)^x \cdot e^{-\lambda \cdot t}}{x!}, x = 0,1,2,3. \quad (1)$$

The random discrete variable *x* (number of failures in a day) can take values from 0 to 3, meaning there is possibility that there are no failures in a day, but also 1, 2 or 3. The probability that there will be no failures in a given period of time is nothing else but the reliability of the system.

$$f(0) = P(X = 0) = \frac{(\lambda \cdot t)^0 \cdot e^{-\lambda \cdot t}}{0!} = e^{-\lambda \cdot t} = R(t) \quad (2)$$

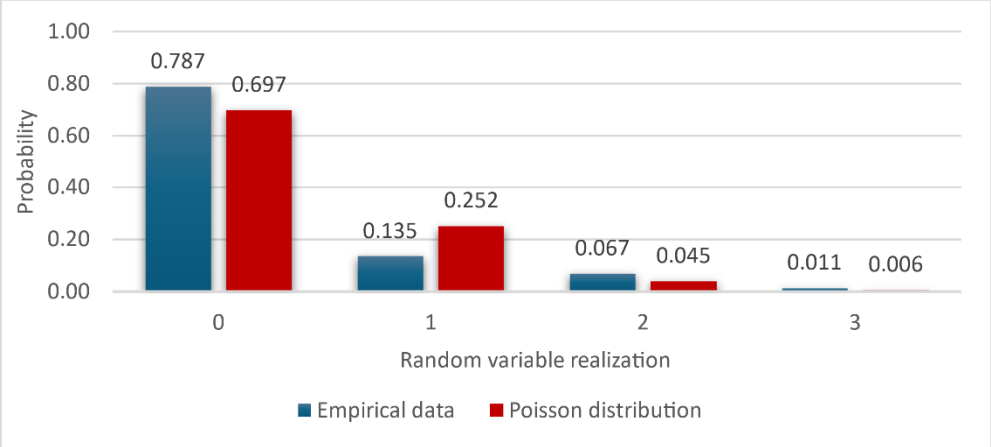

Figure 2. Probability distribution of a number of failures in a day

When it comes to downtime distribution, the results of K-S testing showed that it can be approximated with The 2nd order Erlang theoretical distribution defined by the rate parameter λ_2 = 0.046362906 (and shape parameter k = 2) with the relevance threshold of α = 0,01 (Figure 3). Delays were recorded and measured in minutes.

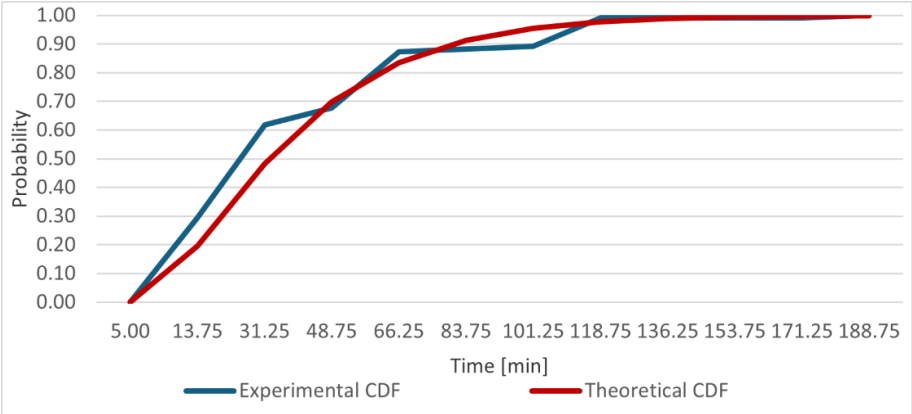

Figure 3. Bulldozer's downtime distribution

4.3. Reliability analysis

As has already been said, the reliability of the bulldozer (the probability that it will perform its specified function for a given time) can be derived from Poisson's PDF and has an exponential distribution form. Therefore, the parameter of the distribution (λ_1) will be equal to the failure intensity (λ_1 = 0.360827375 1/day = 0.015034474 1/h).

$$R(t) = e^{-\lambda_1 \cdot t} = e^{-0.015034474 \cdot t} \tag{3}$$

Conversely, the concept of unreliability (or failure function) includes the probability that the system will fail within a specified time frame, which can be determined by following Equation 4.

$$F(t) = 1 - e^{-\lambda_1 \cdot t} = 1 - e^{-0.015034474 \cdot t} \tag{4}$$

Figure 4 provides a graphical representation of the change in the bulldozer's reliability and unreliability over a period of one month, approximately 30 days (720 h).

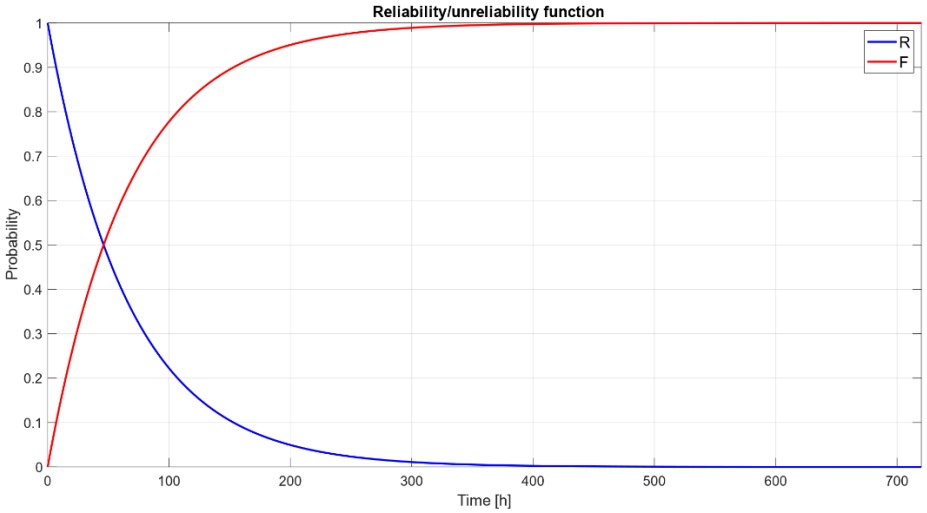

Figure 4. System's reliability and unreliability over time

The average delay time due to the failures (MDT) is equal to the expected value of the downtime distribution:

$$MDT = \frac{k}{\lambda_2} = \frac{2}{0.046362906} = 43.14 \text{ min} \approx 0.72 \text{ h} \quad (5)$$

4.4. Risk assessment model

The FMEA method, or Failure Modes and Effects Analysis, is one of the most widely used instruments for risk assessment and management in complex technical systems. It was officially defined and detailed by the international standard ISO/IEC 31010. The method evaluates the risk level using the risk performance number (RPN). Three component indicators, each graded on a scale of 1 to 5, comprise the risk performance, accurately characterizing risk as a whole (Đenadić, 2022).

Equation 6 provides the overall RPN for all failures, which ultimately represents the overall risk level of bulldozers.

$$RPN = S \cdot O \cdot D \quad (6)$$

The severity of the consequences (S) is the first partial indicator. In order to accurately assess the incident's intensity, this indicator seeks to quantify its impacts. The total costs (TC) incurred due to the bulldozer not operating are used to determine the severity of the failure. These includes lost revenue and repair expenses. Bugaric et al. (2022) state that the company loses 66.6125 EUR for each hour when a machine is out of commission, or that ATC = 66.6125 [EUR/wh]. In light of this, Table 1 presents a ranking of the event's severity.

Table 1. Severity of consequences evaluation

Criterion	Severity of consequences	Rank
$TC \leq 100$ [EUR]	Very Low	1
$100 < TC \leq 300$ [EUR]	Low	2
$300 < TC \leq 600$ [EUR]	Medium	3
$600 < TC \leq 900$ [EUR]	High	4
$TC > 900$ [EUR]	Very High	5

The overall severity rank is evaluated by calculating the average total cost per failure:

$$ATC \cdot MDT = 66.6125 \cdot 0.72 = 47.96 \text{ EUR} \quad (7)$$

Thus, the overall severity of the consequences is evaluated as Very Low (S = 1).

O stands for the probability of occurrence, which is another partial indicator. It represents the degree of uncertainty, or the likelihood that an unforeseen event, a failure, will transpire. Table 2 outlines the evaluation procedure based on the system's unreliability. Table 3 examines the chance of failure in four different scenarios to show how this indicator changes over time. The bulldozer enters a phase with a "Very High" likelihood of occurrence during the 5th day of operation, meaning that a failure is almost unavoidable.

Table 2. Probability of occurrence evaluation

Criterion	Probability of occurrence	Rank
$F(t) \leq 0.2$	Very Low	1
$0.2 < F(t) \leq 0.4$	Low	2
$0.4 < F(t) \leq 0.6$	Medium	3
$0.6 < F(t) \leq 0.8$	High	4
$F(t) > 0.8$	Very High	5

Table 3. Four scenarios that illustrate how second risk dimension (O) changes through time

Scenario	Operating time	Probability of failure	Rank
I	1 work shift = 8 h	$F(8) = 0.1133$	1
II	1 day = 24 h	$F(24) = 0.3029$	2
III	3 days = 72 h	$F(72) = 0.6612$	4
IV	5 days = 120 h	$F(120) = 0.8354$	5

The third partial indicator, detection rate (D), shows how a failure mode will be identified by controls and inspections and also quantifies its impact based on how simple it will be to identify the problem's cause when a failure happens (Wang et al., 2012). Table 4 presents the ranking of the detection rate of events according to the type of failure.

Table 4. Detection rate indicator evaluation

Criterion	Detection rate	Rank
/	Very High	1
Failure type is mechanical.	High	2
Failure type is technological or due to external influences.	Medium	3
Failure type is due to power/electricity.	Low	4
/	Very Low	5

The general detection rate of failures in bulldozers is estimated based on an expected value of ranks:

$$EV(R_D) = \sum_{i=1}^{4} p_i \cdot R_{Di} = \frac{61}{83} \cdot 2 + \frac{2}{83} \cdot 3 + \frac{0}{83} \cdot 3 + \frac{20}{83} \cdot 4 = 2.51 \quad (8)$$

The final detection rate will be rounded up to a larger figure, $D = 3$, in accordance with the previously established process, which prioritizes safety and calls for evaluating each indicator with a whole number.

Following the suggestions in a previously defined methodology by Spasojević-Brkić et al. (2023), the overall risk classification along with suggested actions is given in Table 5. The overall risk of the bulldozer's performance, including the worst-case scenario when it comes to unreliability, is equal to:

$$RPN = S \cdot O \cdot D = 1 \cdot 5 \cdot 3 = 15 \quad (9)$$

Table 5. RPN interpretation

Criterion	Risk level	Suggested actions
$RPN \leq 25$	Very Low	Regular cost analysis once in a year.
$25 < RPN \leq 50$	Low	Cost analysis once in 6 months.
$50 < RPN \leq 75$	Medium	Cost analysis once in 3 months.
$75 < RPN \leq 100$	High	Cost analysis every month.
$RPN > 100$	Very High	Cost analysis as soon as possible.

The rental cost of a machine at a market rate of 70 EUR/wh is the main boundary that determines its economic lifetime (Bugaric et al., 2022). Consequently, the machine is no longer economically viable, and its replacement is advised when the cost analysis results show that the machine maintenance is more expensive than the rental price, i.e., ATC ≥70 [EUR/wh].

To conclude, overall risk can be evaluated as "Very Low", which implies that cost analysis should be done once a year. A graphical representation of the highlighted bulldozer's RPN in a three-dimensional risk matrix is shown in Figure 5.

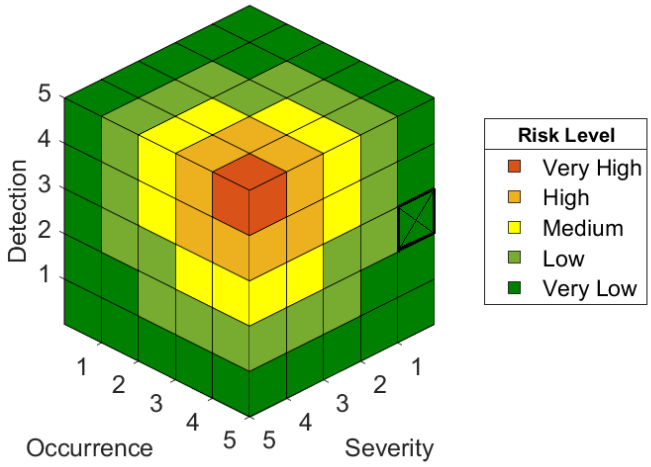

Figure 5. Bulldozer's RPN in a 3D Risk Assessment Matrix

5. CONCLUSION

Suggestions from recent studies have shown that risk in the mining industry should be examined from the perspectives of strategy and operations, in addition to the already well-known safety-centred view. Based on the Pareto analysis, it was found that the majority of downtime can be attributed to mechanical and technological factors. The chi-square test revealed a correlation between the data and a Poisson distribution. Subsequent reliability analysis revealed that the MDT amounts to 0.72 hours. The FMEA analysis determined that the bulldozer's overall performance risk is 15. Based on the rating provided, it is recommended that the cost analysis be conducted on an annual basis.The study's findings demonstrated that, because the monitored bulldozer belongs to the lowest defined risk class, its use is currently economically justifiable. In other words, it brings in more revenue than it costs to operate. The probability that the machine will turn a profit decreases as its risk level rises through years of operation. Not only do unplanned machine breakdowns generate direct economic consequences for the company, but after each of them occurs, the amortization process speeds up. Hence, the risk evaluation method can be a useful way to gain more awareness of the possibilities that old machine replacement generates, either by outsourcing or purchasing a new one. The main limitations of this research are the small sample size at first and the absence of reference risk scores for other auxiliary machines. Therefore, in order to maximize the utility of the remaining equipment, research efforts should concentrate on growing the current sample (or collecting a new, larger one) and applying the established methodology to it.

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Review Article

AN OVERVIEW ON OPTIMAL MODELING OF HYBRID RENEWABLE ENERGY SYSTEMS FOR ENHANCING ENERGY MANAGEMENT STRATEGIES

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Abstract: To meet the growing demand for electricity generation, the use of renewable energy sources represents an ideal alternative to traditional resources. Compared to individual systems utilizing renewable energy sources, hybrid renewable energy systems (HRES) for electricity generation combine renewable energy sources and/or fossil fuels, providing more reliable electricity supply while achieving environmental and economic sustainability. It is crucial to optimally model all components of hybrid energy systems to meet overall electricity demands with minimal investment and operational costs. This paper provides an overview of currently available commercial software for optimizing hybrid renewable energy systems, with a specific focus on the software HOMER (Hybrid Optimization of Multiple Electric Renewables). Approaches and phases of the optimization process for these systems are presented, as well as key parameters that must be considered during analysis.

Keywords: renewable energy, hybrid energy systems, optimization, simulation tools, HOMER software.

1. INTRODUCTION

The increasing demand for energy, particularly in the electricity sector, over the past few years has been driven by the growing global population, urbanization, and accelerated technological development. Currently, the majority of the world's electricity production comes from fossil fuel resources, which is presented in Figure 1. The figure shows the total production, production from dominant non-renewable sources (coal, oil, natural gas, and nuclear fuel), and production from dominant renewable sources (hydro, wind, solar, and biofuels). Data was gathered from (IEA,2024).

Due to limited reserves of non-renewable energy sources such as coal, oil, and natural gas, there is an increasing reliance on these fuels, which directly impacts the economy of each

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country unfavorably. In addition to the adverse economic impact, the combustion of fossil fuels has negative effects on human health and climate change due to greenhouse gas emissions.

Achieving sustainable energy supply involves economic viability, reliability, and environmental acceptability, utilizing local resources and grids efficiently. The use of renewable energy sources (RES) as clean, sustainable, and efficient alternatives to fossil fuels is increasingly crucial for achieving sustainable development and represents the most effective solution to address these challenges.

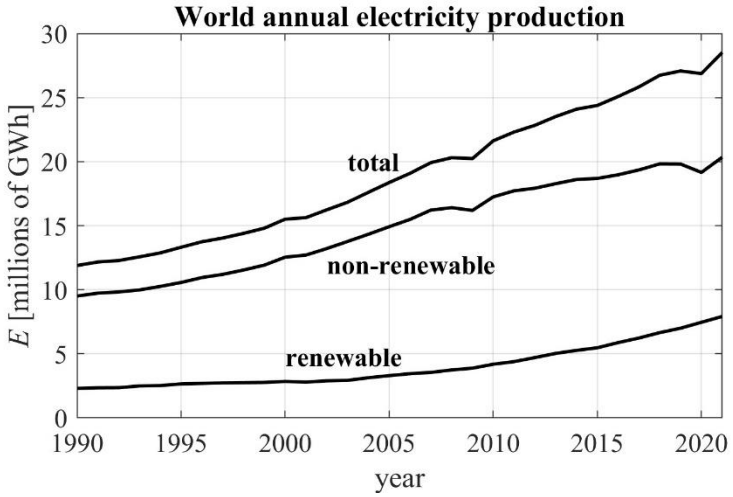

Figure 1. World electricity generation by source (IEA,2024)

Each form of renewable energy system, such as solar, hydroelectric, biomass, wind, oceanic, and geothermal energies, has specific advantages tailored to particular purposes and needs. However, when RES are used individually, problems can arise related to high investment costs and reduced supply security due to their direct dependence on weather and climate conditions. Their unpredictability, especially pronounced in solar and wind energy, may lead to RES not fully meeting demand requirements. Therefore, efficient storage solutions are crucial to ensuring system reliability, achieving a balance between electricity supply and demand, and managing excess electricity production. Mega-batteries and pumped hydroelectric storage facilities are currently the most commonly used high-capacity storage systems (VargasSalgado et al., 2022). However, implementing such systems can be challenging in places like islands where land availability is limited. There are also other energy storage techniques, such as hydrogen storage, compressed air storage, thermal energy storage, etc. These are all described in detail in (Mitali et al., 2022)

Hybrid renewable energy systems (HRES) for electricity generation utilize a combination of renewable energy sources and/or fossil fuels, along with energy storage and electronic devices. HRES thus provide increased energy supply reliability and system efficiency, contribute to reducing greenhouse gas emissions, and also provide access to electricity in remote and rural areas. Various configurations of hybrid energy systems can be used for electricity generation, including, for example, biomass-PV-wind, PV-wind-diesel, wind-PV, hydro-wind-PV, PV-wind-hydrogen/fuel cell energy systems, etc. Hybrid energy systems have the flexibility to be connected to the grid or operate independently (stand-alone) to meet local energy needs. The choice of mode depends on factors such as grid accessibility, weather conditions, grid electricity costs, and specific site conditions. Stand-alone HRES are typically used in remote and rural areas, where additional energy sources such as energy storage and traditional energy resources are utilized to increase energy supply reliability, while excess

energy from renewable sources is stored during surplus production. Grid-connected HRES are usually employed in locations such as hospitals, factories, universities, and others. For enhanced economic sustainability, during periods of low grid electricity prices, grid electricity is used to charge energy storage, while during periods of high grid electricity prices, renewable energy sources are used to meet electricity demand, with surplus electricity being sold back to the grid.

The current situation in Serbia is such that the main source of electricity production comes from non-renewable energy sources, mainly coal, which can be seen in Figure 2, where the main energy sources for electricity production in Serbia are presented from the latest available data given for the year 2021. (IEA, 2024). In 2022, renewables accounted for around 27.5% of electricity generation in Serbia (IEA, 2024). This percentage should be higher, considering that Serbia has great potential for using renewable energy sources such as solar, biomass, and hydroenergy.

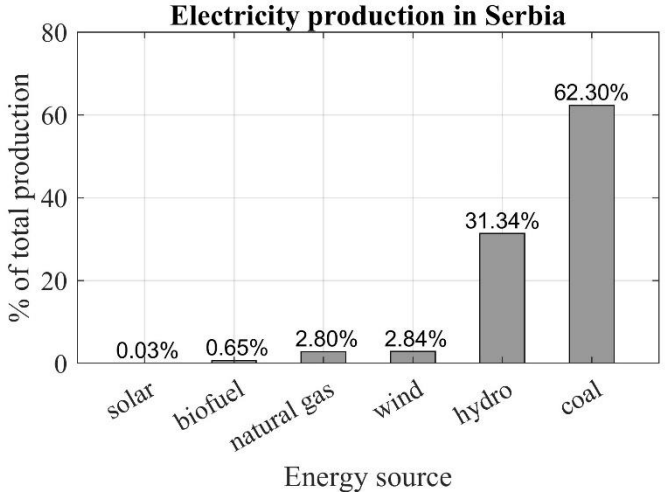

Figure 2. Electricity generation by source in Serbia (IEA, 2024)

Although the use of solar photovoltaic systems appears low, Serbia has favorable conditions for photovoltaic power plants, with approximately 270 sunny days per year and average solar radiation about 30% higher compared to Western Europe. The average solar radiation intensity is 1,200 kWh/m^2 annually in northeastern Serbia, 1,400 kWh/m^2 annually in central Serbia, and 1,550 kWh/m^2 annually in southeastern Serbia (ITA, 2024). Increased implementation of hybrid energy systems in Serbia would bring about more energy-efficient solutions, positively impacting the economy, environment, and quality of life.

2. SIZING AND OPTIMIZATION TOOLS FOR HRES

Comprehensive and thorough techno-economic analyses are necessary for the proper design of HRES components and system optimization, ensuring efficient and cost-effective utilization of renewable energy sources. Optimization depends on various factors such as the availability of renewable and non-renewable resources, suitable existing locations, system costs, and incentive programs.

The development of computer technology has contributed to easier analysis of this complex requirement for optimizing hybrid energy systems. Various techniques for designing and optimizing hybrid energy systems have been studied in literature and scientific papers, such as genetic algorithms (GA), simulated annealing (SA), and particle swarm optimization (PSO) (Erdinç & Uzunoğlu, 2012). Additionally, the latest approaches in designing, analyzing,

optimizing, and economically planning HRES involve the use of highly sophisticated commercial software to identify the optimal location and configuration of hybrid systems. This is achieved by comparing the performance and production costs of different configurations. The use of simulation software facilitates and simplifies the process of modeling and integrating these systems in real-time, enabling greater utilization of renewable energy sources for electricity production at minimal costs. Several software tools have been developed in recent years (for example, HOMER, iHOGA, RETScreen, Hybrid 2, TRNSYS, etc.). One of the most well-known, widely used, and freely available simulation software for sizing hybrid energy systems is the HOMER program. Table 1 displays the options for analyzing hybrid systems using various software tools.

Table 1. Capabilities for analyzing hybrid system software tools (Sinha & Chandel, 2014)

Tools	Econ. Analysis	Technical Analysis	PV System	Wind System	Generator Set	Storage Device	Bio-Energy	Hidro-Energy	Thermal System
HOMER	+	+	+	+	+	+	+	+	-
HYBRID 2	-	+	+	+	+	+	-	-	+
iHOGA	+	+	+	+	+	+	-	+	-
RETScreen	+	+	+	+	-	+	-	-	-
HYBRIDS	-	+	+	+	-	+	-	-	-
SOMES	+	+	+	+	-	+	-	-	-
RAPSIM	-	+	+	+	+	+	-	-	-
SOLSIM	+	+	+	+	+	+	+	-	-
ARES-1 &II	-	+	+	+	+	+	-	-	-
HYSIS	-	+	+	+	+	+	-	-	-
INSEL	-	+	+	+	+	+	-	-	-
SOLSIM	+	+	+	+	+	+	-	-	-
HybSim	+	+	+	-	+	+	-	-	-
Dymola/Modelica	+	-	+	+	+	+	-	-	-
SOLSTOR	+	+	+	+	+	-	-	-	-
HySim	+	+	+	-	+	+	-	-	-
IPSYS	-	+	+	+	+	+	-	+	-
Hybrid Designer	+	-	+	+	+	+	-	-	-
TRNSYS	+	+	+	+	+	+	-	-	+
iGRHYSO	+	+	+	+	-	+	-	+	-

3. DESCRIPTION OF HOMER SIMULATION SOFTWARE

A micropower system generates electricity, and sometimes heat, to fulfill the energy requirements of a nearby load. Designing and analyzing micropower systems can be quite challenging, mainly because of the numerous design options and uncertainties regarding crucial parameters such as load size and future fuel expenses. The incorporation of renewable energy sources adds complexity since their output can fluctuate intermittently and seasonally and may not always be dispatchable. Additionally, the reliability of renewable resources might also be uncertain.

HOMER (Hybrid Optimization of Multiple Electric Renewables) is a hybrid power system optimization software developed by the U.S. National Renewable Energy Laboratory (NREL). This micropower optimization model is a leading simulation tool tailored to optimize micropower systems, specifically aimed at enhancing small-scale and micro power systems. It is extensively utilized in the design analysis of both grid-connected and standalone Hybrid

Energy Systems (HESs). The software can analyze, simulate, and select the optimal hybrid energy system based on technical, economic, and environmental requirements.

The HOMER software is widely represented in literature and scientific papers for optimizing various configurations of HESs and analyzing different case studies. Comprehensive reviews of various studies utilizing this software can be found in review articles (Sinha & Chandel, 2014; Ram et al., 2022; Bahramara et al., 2016; Kavadias & Triantafyllou, 2021). An application of HOMER for optimal utilization of a HES in telecommunications is given in (Ristić & Božić, 2018) along with useful guidelines for data preparation. The diagrams presented in Figure 3 provide visual representations of the micropower systems that HOMER can simulate.

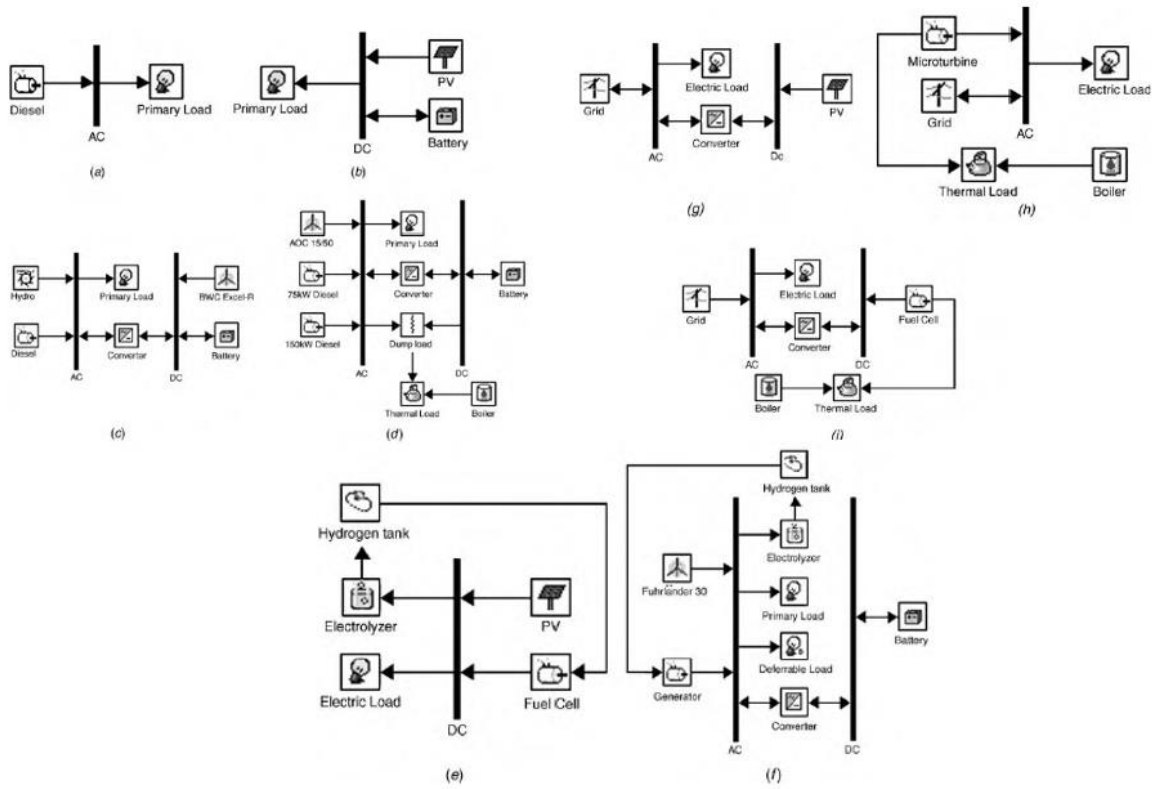

Figure 3. Schematic diagrams of some micropower system types that HOMER models (Farret & Simões, 2005)

In HOMER, a component refers to any part of a micro-energy system that can generate, deliver, convert, or store energy (Farret & Simões, 2005). This software can model ten different types of conventional and renewable energy component models. Components that produce electrical energy from renewable energy sources include photovoltaic (PV) modules, wind turbines, and hydro turbines. Boilers, generators, and the grid can be used by a hybrid energy system in software as necessary. Boilers use fuel to produce thermal energy, and generators use fuel to produce AC or DC electrical energy. Generators can also generate thermal energy by using waste heat. Diesel, natural gas, gasoline, hydrogen, or any other defined fuel can be specified as a fuel resource. The grid as a component in HOMER delivers AC electrical energy to the system grid and accepts excess electrical energy from the system. Two types of energy storage components are batteries that store DC electrical energy and hydrogen storage tanks that store hydrogen obtained by electrolysis (which can be used as fuel for generators). Components used in HOMER for converting electrical energy into other forms include AC-DC

converters and electrolysis units that use excess electrical energy via water electrolysis and produce hydrogen.

When selecting the most suitable hybrid system, the HOMER software conducts simulation, optimization, and sensitivity analysis of the system (Figure 4) (De Dieu Niyonteze et al., 2020). The microgrid simulation process involves modeling various system configurations throughout the 8760 hours in a year.

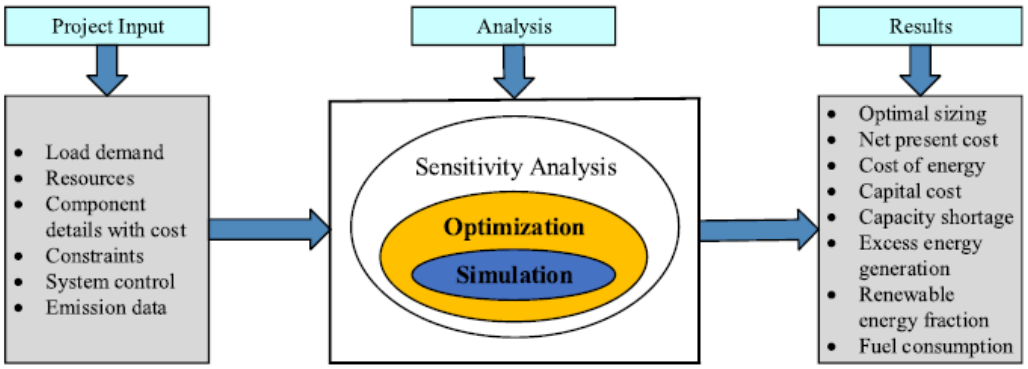

Figure 4. Visualization of HOMER software's schematics (De Dieu Niyonteze et al., 2020)

To simulate various configurations of hybrid energy systems, HOMER software requires six types of different data, namely:

- search area;
- meteorological information (e.g. solar radiation, wind speed, temperature, and stream flow in the format of monthly means or time-series dataset);
- load profile;
- equipment specifications;
- economic data;
- technical data.

One of the key data for simulating HRES is the load profile. Data on actual electricity consumption, inputted into the software as a time series, are essential for system analysis and optimization. However, in cases where this data is unavailable, particularly in analyzing standalone HRES in rural and remote areas, predicting this data becomes necessary, utilizing daily load profiles within the software. If the simulated system includes batteries and a generator, the software requires the introduction of a battery charging strategy. Charging of the battery can be done solely by renewable energy sources or generators, but only under conditions where they produce surplus electricity (Aziz et al., 2022). The simulation process during the analysis of the hybrid system is depicted in Figure 5 (Babu & Ray, 2023).

During the optimization process, technically feasible and optimal system configurations are categorized based on the lowest total cost over the lifecycle of the hybrid system - Net Present Cost (NPC). The technically feasible system that the software considers is one that can meet the needs for electrical energy, thermal energy, as well as other user requirements. The optimization process assists the software user in selecting the best possible system configuration, considering some of the decisive parameters, such as: energy cost (COE), quantity and size of each component, electricity generation, fuel consumption, share of renewable energy sources, pollutant emissions, or the operation strategy of the hybrid energy system.

Following the completion of the simulation and optimization process, an optional sensitivity analysis can be conducted. Sensitivity analysis involves multiple system optimizations and assesses the effects of uncertainties, considering variables and uncertain

parameters that are not user-dependent, such as fuel prices, grid electricity prices, solar radiation, wind speed, interest rates, or the lifespan of photovoltaic modules (Farret & Simões, 2005). Simulation and optimization processes are repeated for each input uncertain parameter, providing insight into how these variable and uncertain parameters affect the system, which can directly impact the selection of a new and more optimal solution.

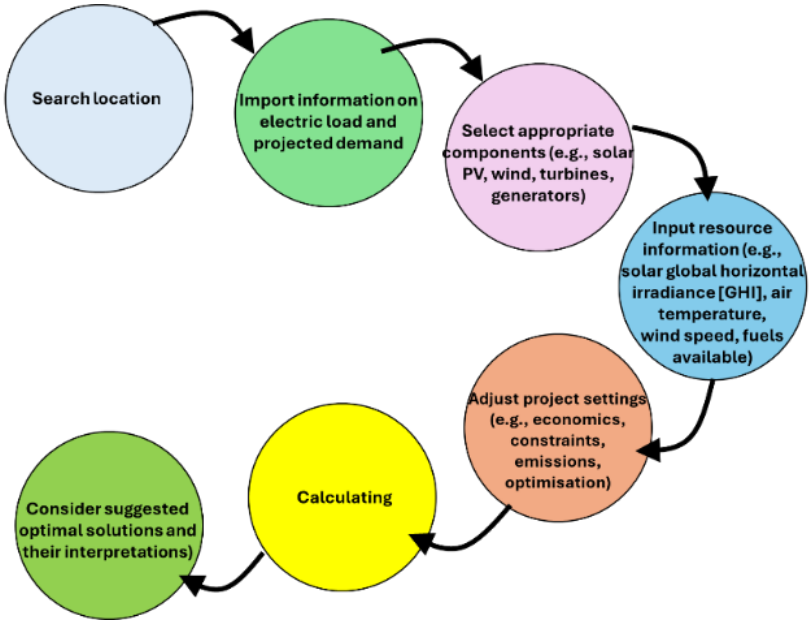

Figure 5. Workflow for HOMER software (Babu & Ray, 2023)

4. THE KEY ECONOMIC AND ELECTRICAL TERMS USED IN THE SOFTWARE

In this subsection, key terms associated with the design and planning of the microgrid model are analyzed (Mehta & Basak, 2020; Tsai et al., 2019; Homer Pro 3.15, 2024; Beza et al., 2021).

4.1. Annual Real Interest Rate

This term is used to determine the discount factor and annualize costs from present cost.

$$i = \frac{i' - f}{1 + f} \tag{1}$$

where i is annual real interest rate, i' is nominal interest rate, and f is expected inflation rate (%).

4.2. Capital Recovery Factor

The Capital Recovery Factor (CRF) is a metric utilized to calculate the present value of an annuity over the lifespan of a project. In equation, t refers to the number of years.

$$CRF(i,t) = \frac{i(1+i)^t}{(1+i)^t - 1} \tag{2}$$

4.3. Net Present Cost (NPC)

Net present cost (NPC), also known as the life-cycle cost of the microgrid system, provides a comprehensive cost assessment including, installation (initial capital cost of the system components), operation (cost related to replacing components during the project's lifespan, maintenance and fuel costs, as well as the cost of purchasing electricity from the grid), and revenue considerations (income from selling power to the grid reduces the total NPC). It represents the financial equation summarizing both costs and revenues, thereby offering insights into the component's financial viability over time. Moreover, HOMER computes the net present cost for individual components as well as for the entire system, enabling a comprehensive assessment of the system's life cycle expenses.

4.4. Cost of Energy

HOMER characterizes the cost of energy (COE) as the average cost per kilowatt-hour (kWh) of useful electrical energy generated by the system. In determining the COE, HOMER divides the yearly cost of electricity production (the difference between the total annualized cost and the expense incurred in meeting the thermal load) by the overall annualized generation of useful electric energy.

$$COE = \frac{C_{\text{ann,tot}} - c_{\text{boiler}} \cdot H_{\text{served}}}{E_{\text{served}}} \tag{3}$$

$$C_{\text{ann,tot}} = NPC \cdot CRF(i, N) \tag{4}$$

$$E_{\text{served}} = E_{\text{pri}} + E_{\text{def}} + E_{\text{grid,sales}} \tag{5}$$

Where $C_{\text{ann,tot}}$ [$/year] represents the total annualized cost of the system (annualized value of the total net present cost), H_{served} [kWh/yr] total thermal load served, c_{boiler} [$/kWh] boiler marginal cost, E_{served} [kWh/yr] total electric load served (primary load, deferrable load, energy sales to the grid), *NPC* net present cost, *N* is project life time (yr) and *i* is the annual real interest rate (%).

The second component in the top part of the equation represents the segment of the yearly cost attributed to fulfilling the thermal load requirement. In scenarios where systems like wind or PV are in use, and they don't cater to any thermal load (where H_{thermal}=0), this component becomes negligible, effectively amounting to zero.

4.5. Renewable Fraction

The Renewable Fraction (f_{ren}), represents the percentage of energy supplied to the load derived from various renewable energy sources such as solar PV, wind, and biomass. A higher RF contributes to reduced costs of energy, carbon emissions, and other related parameters, thereby enhancing the overall efficiency and sustainability of the power system.

$$f_{\text{ren}} = 1 - \frac{E_{\text{non-ren}} + H_{\text{non-ren}}}{E_{\text{served}} + H_{\text{served}}} \tag{6}$$

Where $E_{\text{non,ren}}$ [kWh/yr] represents nonrenewable electrical energy production, $H_{\text{non-ren}}$ non-renewable thermal energy production, H_{served} [kWh/yr] total thermal load served, $E_{\text{grid,sales}}$ [kWh/yr] total energy sold to the main grid, and E_{served} [kWh/yr] total electrical load served in the grid.

4.6. Operating cost

Operating Cost ($C_{\text{operating}}$) refers to the mathematical relationship between the total annualized expenses associated with a component and its total capital investment. The analysis of operating costs provides a quantitative assessment of the component, disregarding its initial capital outlay and installation expenses.

$$C_{\text{operating}} = C_{\text{ann,tot}} - C_{\text{ann,cap}} \tag{7}$$

Where $C_{\text{ann,tot}}$ is the total annualized cost [$/yr] and $C_{\text{ann,cap}}$ is the total annualized capital cost [$/yr].

4.7. Operation and Maintenance costs (O&M):

It includes the costs associated with the operational and maintenance aspects of each component, contributing to the overall O&M expenditure of the system.

5. CONCLUSION

Well-developed energy management strategies and optimal modelling of hybrid energy systems are key to reducing costs and greenhouse gas emissions, ensuring load coverage, and extending the lifespan of system components. In this way, overall energy system performance is improved, providing a sustainable solution with technological and economic benefits. Analysis and modeling of renewable energy systems can be very complex due to their direct dependence on weather and climatic conditions. Compared to renewable energy systems, hybrid renewable energy systems offer greater reliability in meeting local electricity needs, especially in rural and remote areas, as well as in specialized urban areas (universities, factories, hospitals, etc.). Given the main problem encountered in the design and optimization of these systems, the paper provides an overview of currently available commercial software for analyzing these systems, with a special focus on HOMER software, which is one of the most commonly used simulation software for hybrid energy systems. The challenges posed in this paper, which arise during HRES analysis, are addressed by HOMER software through an approach that includes three phases: simulation, optimization, and sensitivity analysis, aimed at finding the most optimal hybrid energy solution. Further analysis should involve case studies using this powerful software to overcome challenges in Serbia.

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INTEGRATED PROCESS PLANNING AND SCHEDULING OF PRODUCTION SYSTEMS BASED ON MOUNTAIN GAZELLE OPTIMIZER

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Abstract: The mass customization paradigm, in conjunction with high market demands, puts a significant burden on contemporary production systems to output a larger quantity of diversified parts. Consequently, production systems need to achieve even higher flexibility levels through physical and functional reconfigurability. One way of achieving these high levels of flexibility is by utilizing optimization of both scheduling and process planning. In this paper, the authors propose to solve an NP-hard integrated process planning and scheduling optimization problem with transportation constraints regarding one mobile robot. The proposed production environment includes four types of flexibilities (process, sequence, machine, and tool) that can be leveraged to optimize the entire manufacturing schedule. Three metaheuristic optimization algorithms are compared on the nine-problem benchmark based on the makespan metric. The proposed Mountain Gazelle Optimizer (MGO) is compared to the whale optimization algorithm and particle swarm optimization algorithm. The experimental results show that MGO achieves most best results, while it is highly comparable on the average best results.

Keywords: Integrated process planning and scheduling, optimization, mountain gazelle optimizer, metaheuristic algorithms, production systems.

1. INTRODUCTION

The manufacturing industry has undergone significant developments in recent years thanks to the Integrated Process Planning and Scheduling (IPPS) methodology (Phanden et al., 2019). This approach is designed to integrate process planning and scheduling activities, enabling businesses to maximize resource utilization and minimize costs while maintaining customer demands and delivery deadlines. IPPS leverages advanced optimization techniques such as mathematical programming or biologically inspired algorithms to generate efficient

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production plans and schedules that meet multiple objectives and constraints. Besides the increased efficiency of the production systems, another key advantage of IPPS is its ability to provide decision support through tools such as Gant charts visualizations of different planning scenarios. These features allow management to evaluate various alternative schedules and select the optimal solution. Methods IPPS problems are designed to tackle the complexity of these optimization problems, employing sophisticated algorithms such as Mountain Gazelle Optimizer (MGO) (Abdollahzadeh et al., 2022), Genetic Algorithms (GA), Whale Optimization Algorithm (WOA) (Mirjalili & Lewis, 2016), Particle Swarm Optimization (PSO) (Petrović et al., 2016), and Mixed Integer Linear Programming (MILP) (Caumond et al., 2009) to generate feasible scheduling plans.

The Mountain Gazelle Optimizer (MGO) is a novel population-based optimization algorithm that takes inspiration from the social structure, hierarchy, and behavior of mountain gazelles. MGO incorporates four critical behaviors of mountain gazelles, namely territorial solitary males, maternity herds, bachelor male herds, and migration in search of food, into its mathematical framework. Each behavior contributes to the algorithm's exploration and exploitation capabilities, making it excellent for balancing exploration and exploitation while achieving good performance across different optimization problems.

Genetic Algorithms (GA) are a class of optimization algorithms that are inspired by the process of natural selection and genetics. They are well-suited for solving complex problems, as they can efficiently search large solution spaces and handle multiple objectives and constraints. The GA involves generating a population of potential solutions (chromosomes) and then iteratively evolving them through selection, crossover, and mutation operations to find optimal or near-optimal solutions. This iterative process mimics the evolution of species in nature, where the fittest individuals are selected for reproduction. The process continues until a satisfactory solution is obtained.

The Whale Optimization Algorithm (WOA) is an optimization technique inspired by the hunting behavior of humpback whales. This nature-inspired algorithm is utilized to optimize solutions in various domains. The algorithm follows three main phases: encircling prey, bubble-net attacking, and exploring for prey. These phases simulate solution exploitation strategy and diversification of the search, respectively. The WOA is well-suited algorithm in different fields because of its simplicity and adaptability.

The Particle Swarm Optimization algorithm draws inspiration from the collective behavior of birds or fish, and is a robust computational algorithm for optimization problems. Its working principle relies on the process of iteratively refining candidate solutions based on a given measure of quality. PSO begins by generating a group of random particles, and then updates them over time to find the best possible solution. These particles move through the solution space by tracking the current optimal particle while also considering their own historically best positions. Thanks to its efficiency, PSO is a widely used optimization algorithm for a variety of problems.

Mixed-integer linear Programming (MILP) is a powerful mathematical optimization technique that is specifically designed to model and solve optimization problems that have linear or integer constraints. MILP formulations are particularly useful for complex IPPS problems that require resource allocation, precedence constraints, and multiple objectives. To solve these formulations, commercially available software such as Gurobi (Achterberg, 2019) is highly efficient and effective, and can provide optimal or near-optimal solutions to even the most challenging IPPS problems.

1.1. Optimization algorithm in IPPS

Numerous research studies have been carried out to analyze optimization algorithms on different benchmarks for IPPS, due to the no free lunch theory of optimization, which states that there is no one best optimization algorithm for all problems (Wolpert & Marcredy, 1997). Therefore, in the following paragraphs, we analyze different research studies regarding IPPS optimization. The paper (Petrović et al., 2019) introduces an innovative methodology that applies the Whale Optimization Algorithm to the IPPS with constraints regarding a single mobile robot. The authors propose numerous objective functions, and different datasets to test the enhanced version of the WOA algorithm. The experimental results demonstrate that WOA achieves better results compared to other optimization algorithms. In the paper (Homayouni & Fontes, 2019) the authors focus on developing an integrated formulation to address the joint production and transportation scheduling problem in flexible manufacturing environments. The study emphasizes the necessity of simultaneous scheduling of machines and Automatic Guided Vehicles (AGVs), as they are closely interconnected in manufacturing systems where parts need to be transported across various machines for different operations. The authors propose a novel MILP model that incorporates two sets of chained decisions: one for machine scheduling and another for AGV scheduling. These sets are linked through completion time constraints for both machine operations and transportation tasks. Computational experiments conducted using the Gurobi commercial software on benchmark problem demonstrate the effectiveness of the proposed model in finding optimal solutions.

The study detailed in (Homayouni et al., 2020) explores the utilization of a multistart biased random key genetic algorithm augmented with a greedy heuristic to discover high-quality solutions for the job shop scheduling problem with transportation constraints. This approach synchronizes four interconnected aspects: job routing, machine scheduling, vehicle allocation, and transportation timing, with the goal of reducing the total completion time, or makespan. The experimental findings underscore the method's effectiveness across various scheduling problem categories, validated through testing on over 60 cases across two problem sets. Building on this, the authors (Homayouni & Fontes, 2021) introduced a late acceptance hill-climbing strategy to prevent the algorithm from stagnating at local maxima. This technique underwent testing on five datasets, demonstrating its efficacy in optimizing smaller and medium-sized problem instances and delivering competitive outcomes for larger scenarios. The authors of the paper (Petrović et al., 2022) present an innovative methodology using the multi-objective Grey Wolf Optimizer (GWO) to efficiently perform IPPS with material transport systems in intelligent manufacturing systems. The methodology includes a comprehensive analysis, mathematical formulation of 13 novel fitness functions, and a strategy for optimal exploration of the multi-objective search space. The effectiveness of the enhanced GWO algorithm is quantitatively compared with other metaheuristic methods across 25 benchmarks. The experimental results indicate that the enhanced GWO algorithm outperforms the other algorithms in terms of convergence, coverage, and robustness in finding optimal Pareto solutions. The paper (Utama et al., 2024) introduces a novel application of the MGO algorithm for optimizing the no-wait flow shop scheduling problem with the aim of minimizing industrial energy consumption. The MGO algorithm is implemented with the Large Rank Value procedure. The MGO is compared to GWO, GA, PSO, Coati Optimization Algorithm, and Fire Hawk Optimizer, on three different experimental setups. The One-Way ANOVA statistical tests were performed to show the statistical significance of the obtained results, which show the advantages of the proposed MGO algorithm.

Different from other approaches in this paper, the Mountain Gazelle Optimizer (MGO) algorithm is utilized for IPPS with single transportation vehicle constraints. The MGO was

selected due to its advantages regarding diverse strategies for exploitation and exploration, which are necessary for finding the optimal solution for optimization problems with such vast solution space, such as IPPS.

2. THE MOUNTAIN GAZELLE OPTIMIZER

The Mountain Gazelle Optimizer represented one of the newly developed nature-inspired population-based optimization algorithms, which found its inspiration behind the social hierarchical structure of mountain gazelle herd (Fig. 1).

Figure 1. Social structure of mountain gazelles with male in the middle

The mathematical framework of the MGO algorithm includes four behaviors of mountain gazelles: 1. Territorial Solitary Males (TSM), 2. Maternity Herds (MH), 3. Bachelor Male Herds (BMH), and 4. Migration in Search for Food (MSF). Each gazelle in the population represents a solution to the optimization problem (X) with D solution parameters. Many random numbers are defined within the MGO algorithm, and their notations are as follows. The r defines random numbers that undergo uniform distribution within [0, 1] range, vectors of random numbers drawn from normal distribution with zero mean and standard deviation of one are defined as $N(D)$, with D being number of elements, and random integers in [1, 2] range are defined as r_i. In order to mathematically define four behaviors, firstly, four coefficients need to be defined (1):

$$Cof = \begin{cases} a + 1 + r_1 \\ a \cdot N_1(D) \\ r_2(D) \\ N_2(D) \cdot N_3(D)^2 \cdot cos\left(2r_3 \cdot N_4(D)\right) \end{cases}, \tag{1}$$

where $a = -1 + iter \cdot \left(\frac{-1}{max\_iter}\right)$. Afterward, vector F is defined as (2):

$$F = N_5(D) \cdot exp\left(2 - iter \cdot \frac{2}{max\_iter}\right). \tag{2}$$

The second part of the multiplication of *F* starts with values larger than 1 (depending on the maximum number of interactions) and exponentially converges to 1 with iterations, leaving a simple normal random vector in the last iteration. Now, all relevant values are defined to calculate the young male heard coefficient vector defined as *BH* (3):

$$BH = X_{ra} \cdot r_1 + M_{pr} \cdot r_2, \tag{3}$$

where X_{ra} is a randomly selected solution from the last third of the population; since the solutions are sorted in the acceding order, these represent the worst 33% of the solutions in the entire population. M_{pr} is the mean value for the selected 33% of the population, averaged for each dimension in the input vector. The TSM (4) aspect of the algorithm models the behavior of adult male gazelles that establish and defend territories. It is used in the algorithm to enhance the exploitation ability, allowing the optimizer to search intensively around the best solutions found so far:

$$TSM = X_1 - |(r_{i1} \cdot BH - r_{i2} \cdot X_t) \cdot F| \cdot Cof_r, \tag{4}$$

where X_1 is the best solution obtained so far, X_t is the currently updated agent, and Cof_r is the randomly selected coefficient from (1).

The second behavior, MH (5), consists of females and their offspring, reflecting a balance between exploration and exploitation in the algorithm. This mechanism ensures diversity in the solution space and prevents premature convergence:

$$MH = BH + Cof_r + (r_{i3} \cdot X_1 - r_{i4} \cdot X_{rand}) \cdot Cof_r, \tag{5}$$

where X_{rand} represented a randomly selected solution from the population.

The parameter *Dist* (6) needs to be calculated to model Bachelor Male Herds behavior:

$$Dist = |X_t - X_1| \cdot (2r_6 - 1). \tag{6}$$

The third behavior, BMH (7), represents the young male gazelles, and it is used to explore new areas in the search space, contributing to the algorithm's exploration capabilities.

$$BMH = X_t - Dist + (r_{i5} \cdot X_1 - r_{i6} \cdot BH) \cdot Cof_r, \tag{7}$$

Finally, Migration in Search for Food (8) is modeled with a random search mechanism, that allows algorithm to avoid local optima and ensure comprehensive exploration of the search space:

$$MSF = (lb - ub) \cdot r_7 + lb, \tag{8}$$

where *lb* and *ub* are the lower and upper bounds of the parameter space. As it can be seen, MSF is a uniform random sampling of values in the parameter space, which allows MGO to search the entire parameter space even if the initial solutions are not generated well.

2.1. The MGO algorithm for IPPS

Process plans within the production environment are characterized by different types of flexibilities that can influence the final scheduling plan. This paper considers the following flexibilities: process plan, sequencing, machine, and tools. Process plan flexibility means that each job can be done by employing different manufacturing operations or sequences of operations. Sequencing refers to the ability to change the order of manufacturing operations within a job. Machine and tool flexibilities refer to the possibility of selecting alternative machines and tools for each manufacturing operation. Moreover, jobs are transported between machines by a single mobile robot. For the IPPS problem, each valid solution contains four strings (Petrović et al., 2019) that are used to represent a selected sequence of operations, process plans, selected machines and tools for each operation. Therefore, the optimization process aims to select the optimal values for all strings, which results in the minimal time required for the machining of all jobs, i.e., minimizing the makespan cost function. Finally, the implementation of MGO optimization for the IPPS problem is given in Table 1.

Table 1. Pseudo-code of MGO algorithm implemented for IPPS problem

1.	**Input**: Data for (i) the set of jobs, (ii) the set of alternative process plans for each job, (iii) the set of available machines and tools for each operation, processing times for all operations, and transport times between all machines. Definition of algorithm parameters: population size (N), maximum number of generations.
2.	Initialization of all strings for the whole population
3.	Calculation of cost function value for each gazelle
4.	**for #1** every generation
5.	Select a leader
6.	**for #2** every gazelle
7.	Generate new solution for all IPPS strings according to equations (4), (5), (7), (8)
8.	**endfor #2**
9.	Calculate the cost function value for the entire new population and select N best solutions for the new generation
10.	**endfor #1**
11.	Save results

3. EXPERIMENTAL RESULTS

An experimental evaluation of the proposed algorithm is carried out on a benchmark containing 9 problems, where each problem contains 6 jobs manufactured on 10 machines using 20 different tools. The proposed MGO algorithm is compared to two state-of-the-art algorithms optimization algorithms, namely WOA and PSO. Each algorithm is evaluated five times on each problem. The results of the experimental evaluation are shown in Table 2. The algorithms are compared based on two metrics, the best and average value achieved within five experimental evaluations. As it can be seen, the MGO algorithm achieves most (4/9) best results, which demonstrates the advantage of the MGO's convergence properties. On the other hand, both MGO and PSO achieved the same number of average best results, indicating that MGO can get stuck in local optima in certain experimental evaluations.

Table 2. Experimental results

Problem	best			average		
	WOA	PSO	MGO	WOA	PSO	MGO
1	**133**	163	146	**172**	201	173
2	169	192	**149**	179	230	**172**
3	288	**240**	248	309	**265**	**265**
4	143	**126**	140	168	**133**	159
5	248	**238**	262	277	**251**	286
6	**157**	202	170	**170**	227	230
7	287	271	**254**	329	293	**282**
8	145	135	**129**	155	161	**135**
9	150	137	**108**	175	**151**	175

The convergence curves of the best evaluation of all three algorithms for problems 2, 8, and 9 can be seen in Figure 2. For problems 2 and 8, all the algorithms converge to their optimal values within the first 40 iterations, indicating that their exploration capabilities are sufficient for the considered problems. On the other hand, for problem 9, PSO still manages to achieve a better solution even after 47 generations, indicating that it can benefit from a larger number of generations.

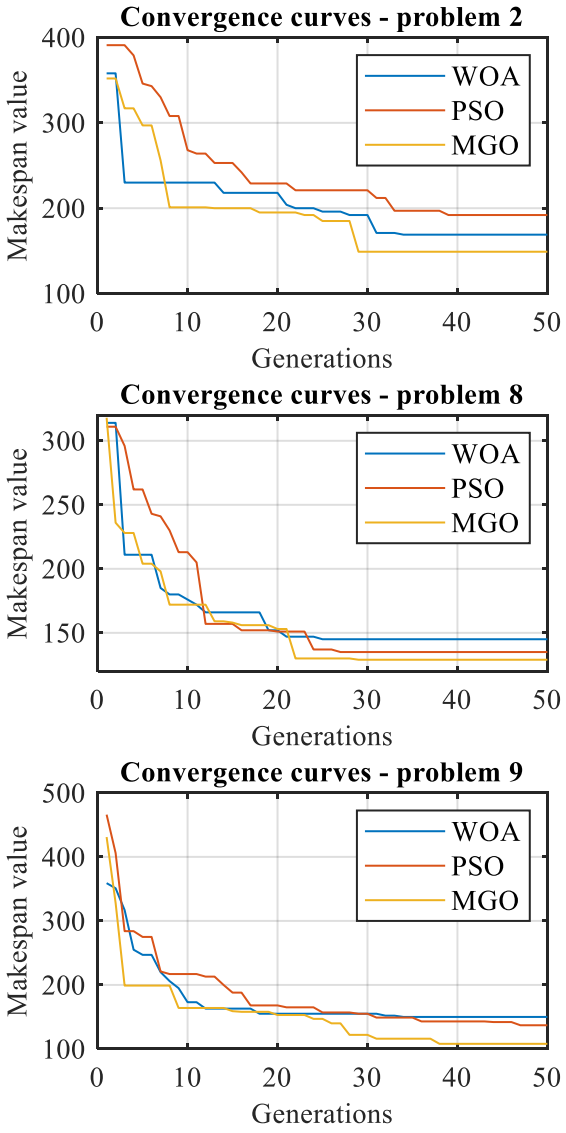

Figure 2. Convergence curves for the best run of three analyzed algorithms

Figure 3. shows the Gantt charts for the best experimental evaluation of the MGO algorithm, again for problems 2, 8, and 9. Each Gantt chart is utilized to represent the sequence of manufacturing operations, the machines that are used, operation duration, and actions the mobile robot needs to perform to transport the jobs from machine to machine. Mobile robot has three actions that it can perform: moving jobs to the machine for the subsequent operation, moving to the machine where the previous operation of the job is manufactured, and waiting for the machine to finish the current operation of the job.

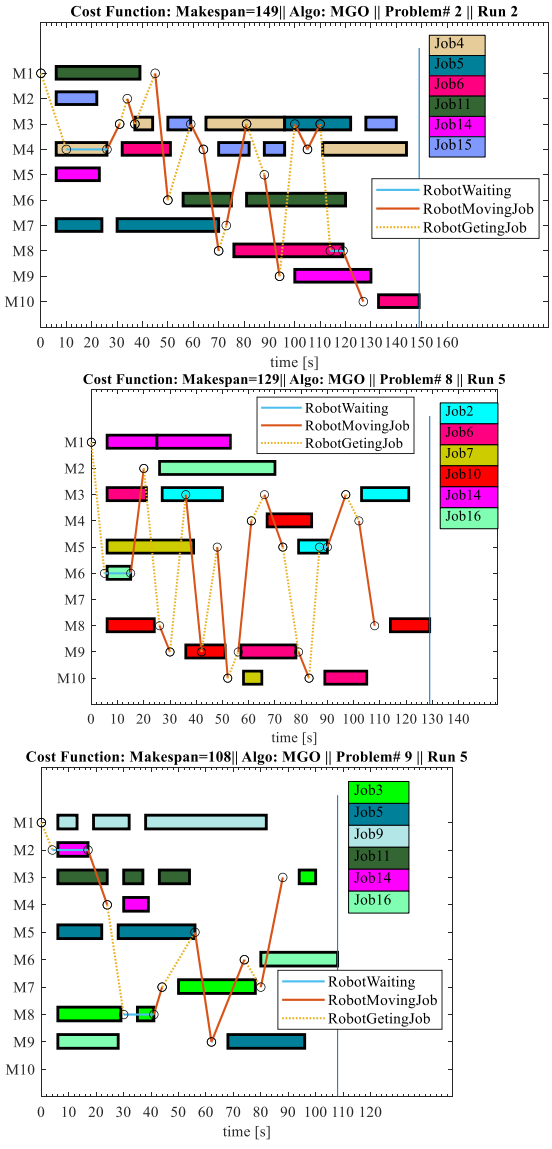

Figure 3. Gantt charts of three problems

4. CONCLUSION

In this paper, the authors propose a novel approach for integrated process planning and scheduling problems based on the mountain gazelle optimization algorithm. The optimization of the production process planning and scheduling is performed based on the makespan metric. The proposed algorithm is compared to two state-of-the-art optimization algorithms. After experimental evaluation with nine different problems containing six jobs, 10 machines, and 20 tools, the proposed MGO algorithm has shown the best convergence properties. However, the MGO achieved the same number of average best results as the PSO. Therefore, improvements in the exploration capabilities of the MGO algorithm can be investigated in the future.

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THE INTEREST OF STUDENTS AND GRADUATES IN FAMILY BUSINESSES

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Abstract: The main aim of this paper is to highlight if there is an interest of the younger generation towards starting a family business with members in the first or second generation. The data were collected by applying an online questionnaire in 2023 on 201 students and graduates of University of Craiova in Romania. The structure of the survey was established within the INTERGEN international project and follows the intentions of youngsters in time, by applying the survey each year. The results show that even if there is an interest in starting a business, the respondents would prefer to be independent and not be too linked with their families. The findings are useful for academic management in orienting the curricula towards the interests exhibited by young generations, but also for adjusting national strategies meant to support small businesses.

Keywords: family business, generation Z, entrepreneurship, family, INTERGEN.

1. INTRODUCTION

Starting a business and being an entrepreneur is challenging but also rewarding. The main benefits are related to a higher level of independence, control, freedom and also a safety net in times of crisis. During the COVID-19 pandemic, many people lost their jobs (Blustein et al., 2020; Galea & Abdalla, 2020), and small businesses, including family businesses, were also affected. The difference is that when you have your own business, at least you feel in control, you can make adjustments and you can start again when things get better. A study conducted in Japan by Amann & Jaussaud (2014) compared the resilience of family businesses and non-family businesses in challenging and difficult times such as a crisis. Their results show a higher resilience for family businesses. Definitely, there are other factors that can influence recovery and resilience such as the culture and the closeness between family members. Dyer Jr. & Panicheva Mortensen (2005) studied the differences in Lithuania and noticed a similar pattern, the explanation provided being related to the fact that people can more easily have access to the support provided by other family members.

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Many studies (Kusumawardani & Richard, 2020; Chillakuri et al., 2022) investigated the interest of youngsters towards the idea of starting a business or a family business if they want to found an organization with other relatives. Compared with non-family businesses, those founded and controlled by family members have both advantages (independence, control, rapidity in implementing new ideas) and challenges (financial difficulties, low visibility at the beginning, high competition), ideas expressed in several papers (Miller & Le Breton-Miller, 2003; Habbershon, 2006; Wang et al., 2015). Carney (2005, p. 249) emphasizes the advantages of family-owned businesses especially in "scarce environments" and "emerging markets".

In this paper, I focus on the interest of students and graduates in Romania in starting a family business or getting engaged in a family business that already exists. This case study is useful for replication or comparison with other developing economies in Eastern and Central Europe which might share many common aspects. The impact of former communist policy systems on entrepreneurship in general or family businesses in particular has been studied by many authors (Zapalska & Zapalska, 2000; Stoica, 2004; Duvanova, 2007; Roberts & Zhou, 2010; Tien, 2021). Communist years before 1989 shaped mentalities and culture and many traits are seen in the attitude and interests even in younger generations. Their parents educated them while also transmitting values that were defined in those times of oppression, lack of freedom, individuality and lack of trust in others. In previous research, we investigated the same intention of youngsters but during the COVID-19 pandemic which might have influenced the students' responses (Puiu et al., 2022).

2. RESEARCH METHODOLOGY

The research started by defining a few research questions (RQ) related to the interest exhibited by students and graduates in Romania about the desire to start a family business, while also focusing on their perception regarding the support they might expect from other family members in the first, second or third generation (with siblings, parents or grandparents).

The RQs defined in the present research are the following:

RQ1: Are students and graduates in Romania more interested in being employees in a big company than starting their own business?

RQ2: Are students and graduates expecting the support of family members when starting a business?

RQ3: Are students and graduates in Romania more willing to start a non-family or a family business?

RQ4: What traits exhibit respondents that might explain their preferences?

The research involved sending a Google form by e-mail and Facebook to more than 800 students and graduates from the University of Craiova, Romania in 2023. We got 201 valid answers for the survey whose structure was established within the INTERGEN project. We used descriptive statistics to offer a better understanding of the answers for the RQs established.

3. RESULTS AND DISCUSSION

To answer to RQ1, we addressed two questions to students and graduates in our sample. The questions used a scale from 1 to 5, where 1 was No, 2 - Rather no, 3 - Neutral, 4 - Rather yes and 5 – Yes. In Table 1, there is a summary of answers to the questions: *Do you prefer to work in a big company?* and, respectively, *Do you want to have your own business?*

Table 1. Comparisons of answers regarding the preference for being employees in a big company vs starting their own business

Do you prefer to work in a big company?	%	Do you want to have your own business?	%
No	9	No	4.5
Rather no	7	Rather no	2.5
Neutral	20.9	Neutral	17.4
Rather yes	23.9	Rather yes	18.9
Yes	39.2	Yes	56.7

We notice that more students and graduates prefer to start their own business (75.6% said Yes and Rather Yes) compared with being employees even in a big company (63.1%) such as a multinational one which might be seen as a way of having a higher wage. Still, even if the difference shows a preference for entrepreneurship, the share of those also choosing a career in a big company is important (almost two-thirds of the respondents).

For answering RQ2, we addressed several statements to the respondents about the support they expect from family members or even ask for it, but also in general which might show how close are the relationships between family members. These statements using the same scale as before are the following: *I am sure that my family will support me by any means*; *To start something, I need the support of my family and friends*; *I can persuade my parents to give me some financial capital to start a business*. The answers are summarized in Table 2.

Table 2. Summary of answers regarding the support expected or needed from family and friends

I am sure that my family will support me by any means	%	To start something, I need the support of my family and friends.	%	I can persuade my parents to give me some financial capital to start a business.	%
No	4.5	No	26.9	No	16.9
Rather no	4	Rather no	24.4	Rather no	13.9
Neutral	10.4	Neutral	13.9	Neutral	16.4
Rather yes	12.4	Rather yes	17.9	Rather yes	14.9
Yes	68.7	Yes	16.9	Yes	37.8

The results in Table 2 are interesting because, on one hand, respondents were sure of the support they would receive from their families (81.1%), but on the other hand, they did not recognize the need for support (51.3%). This difference shows us the difficulty in acknowledging the fact that they might ask for help. Also, if faced with the option to persuade their parents to give them money to start their business, only 52.7% are convinced that they can do that. We notice that they expect more to receive support than are willing to ask directly for it. This can be explained by traits inherent to their young age (high ego, perceiving asking for help with being weak and vulnerable, entitlement because parents should help them without asking), with most respondents being in their twenties. Answering RQ2, yes, students and graduates expect family support even more than they are willing to ask for.

Starting a business and being an entrepreneur does not mean that you want to do that with your family. So, to answer RQ3, we addressed several statements to students and graduates, using the same scale. The statements are the following: *I am ready to start my own business without any support from friends and family* (S1); *I would feel safer if my parents were suppliers or contractors for my business because I trust them* (S2); *In my business plans, I would include my relatives* (S3); *I would feel supported if I had a business with my life partner*

(S4); *I would like to have a completely independent business without any connection to my family* (S5); *I would prefer to have business relations with my family than a completely independent business* (S6); *I would like to have an intergenerational business with my parents* (S7); *I would hire my parents as employees in my business* (S8); *I would have my parents as subcontractors for my business* (S9). The answers are summarized in Table 3.

Table 3. Summary of answers regarding the preference for a family business or a completely independent one

S1	%	S2	%	S3	%	S4	%	S5	%	S6	%	S7	%	S8	%	S9	%
No	10	No	14.9	No	40.3	No	8	No	8.5	No	29.4	No	22.4	No	23.9	No	22.4
Rather no	9.5	Rather no	6.5	Rather no	20.4	Rather no	4	Rather no	10.4	Rather no	17.9	Rather no	15.4	Rather no	11.4	Rather no	9.5
Neutral	12.9	Neutral	15.4	Neutral	17.4	Neutral	12.9	Neutral	19.9	Neutral	25.9	Neutral	25.4	Neutral	19.4	Neutral	27.9
Rather yes	16.9	Rather yes	20.9	Rather yes	9.5	Rather yes	19.4	Rather yes	13.9	Rather yes	11.4	Rather yes	13.9	Rather yes	17.4	Rather yes	16.4
Yes	50.7	Yes	42.3	Yes	12.4	Yes	55.7	Yes	47.3	Yes	15.4	Yes	22.9	Yes	27.9	Yes	23.9

We notice that students and graduates are exhibiting a higher level of trust in themselves, with 67.6% mentioning that they are ready to start a business without any support from family or friends. We also saw at a previous question, that they are reluctant to ask for help, but expect support from parents. There is an emotional internal conflict exhibited by the students while they try to find the balance between independence and dependency. They appreciate the safety net provided by their parents which they trust. Thus, 63.2% of the respondents would feel safer if their parents were suppliers or contractors for their business. Still, 60.7% of the respondents mentioned they would not include in their business other relatives. This shows a desire to be more independent, but they do not exclude a partnership with their family members (61.2%). Most of the respondents prefer independence in business as answers to S6 show: 47.3% prefer independence in business and only 26.8% would prefer a business with their families. The same is revealed by S7 where 37.8% mentioned they are not interested in starting an intergenerational business. Regarding hiring their parents in their business (S8), most of them (45.3%) answered positively. S9 reveals that 40.3% of the respondents would have their parents as subcontractors in their business which shows their trust in them, similar to the answers to S2. Summarizing, the answer to RQ3 is that students and graduates in our study prefer to develop independent businesses but they do not exclude the support received from parents, hiring them or engaging them as subcontractors or suppliers.

For answering RQ4, we addressed several statements to the respondents to better understand the traits of personality which might explain their preference for non-family businesses. The answers are summarized in Table 4.

Table 4. Summary of answers regarding the traits exhibited by the respondents

You can count only on you to succeed	%	I am satisfied with my lifestyle.	%	My priority is to accomplish important objectives.	%	I excellently accomplish my tasks.	%	I think all the time about the problems I should solve.	%	People around me appreciate and support me.	%	I have a clear goal and direction for my future.	%
No	4	No	4	No	1.5	No	2.5	No	5.5	No	2.5	No	5
Rather no	8.5	Rather no	10	Rather no	2.5	Rather no	3.5	Rather no	7	Rather no	8	Rather no	4.5
Neutral	7	Neutral	12.9	Neutral	4.5	Neutral	15.4	Neutral	6.5	Neutral	12.4	Neutral	18.9
Rather yes	20.4	Rather yes	27.4	Rather yes	25.4	Rather yes	36.3	Rather yes	22.4	Rather yes	27.9	Rather yes	27.9
Yes	60.2	Yes	45.8	Yes	66.2	Yes	42.3	Yes	58.7	Yes	49.3	Yes	43.8

The values in Table 4 reveal the answer to RQ4: the respondents are confident, independent, ambitious, competent, solution-oriented and have a high level of clarity which shows the traits behind their preference for a more independent business instead of a family one. 91.3% of the respondents appreciate that their priority is to accomplish important objectives. 78.6% are confident and trust their competencies to accomplish their tasks excellently. 81.1% are focused on solutions for their problems. They are driven and have a clear vision in their lives (71.7%). 77.2% of the respondents are well-perceived by the people around them which makes them confident enough to start a business on their own.

4. CONCLUSION

The research revealed that students and graduates in Romania are interested in starting a business rather than working in a company. They expect support from their family, especially their parents, but are more inclined to develop an independent business without much reliance on relatives. They do not exclude their parents as employees, suppliers, or subcontractors, but they prefer to be independent. The traits that explain this preference refer to confidence, a good self-image, positivism, being goal and solution-oriented, having clarity, a good support network, and being ambitious.

The results are helpful for academic management in shaping the curricula for courses related to entrepreneurship, but also to public authorities that might stimulate these youngsters with targeted and more adjusted strategies aimed at raising the number of entrepreneurial initiatives in the community.

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EXAMINATION OF THE TAM MODEL EXTERNAL FACTORS' INFLUENCE ON THE PERCEIVED EASE OF USE – THE CASE OF SAP ERP SYSTEM

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Abstract: This paper examines the influence of the external factors of the Technology Acceptance Model (TAM) on the perception of SAP system usability. TAM is a theoretical framework often used to analyze technology acceptance, while the SAP system is a complex Enterprise Resource Planning (ERP) system widely used in organizations. The external factors considered in this research are system complexity, system performance, user manual, social impact and work compatibility. A questionnaire was used to analyze the data using the structural equation modeling (SEM) technique. The results show that of the five external factors mentioned, only two factors have a statistically significant influence on perceived ease of use, namely system complexity and system performance. By considering external variables, these results can provide a deeper understanding of users' attitudes towards SAP ERP. This can help to better analyze and interpret the research results and suggest more effective strategies for the implementation and adoption of the system in companies.

Keywords: SAP, ERP, TAM, external factors, survey

1. INTRODUCTION

The development of Internet technologies and information systems (IS) for the needs of organizations has greatly facilitated the management of business processes. The systems used to support the management of an organization have evolved so that modern Enterprise Resource Planning (ERP) systems have become indispensable (Nwankpa, 2015).

ERP systems play a key role in organizations and provide comprehensive support for resource and process management. When implementing ERP systems, it is important to understand how users will accept and use them. Therefore, the Technology Acceptance Model (TAM) provides a theoretical framework for analyzing and predicting the acceptance of new technologies, including ERP systems. The TAM helps organizations understand the factors that influence user acceptance and adoption of ERP systems, which can be critical to the successful implementation and effective use of these systems in a business environment.

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TAM was originally conceptualized by Davis in 1989. The basic idea of this model was to explain how users perceive the adoption of a new technology (Cao et al., 2021). Since its first appearance in the scientific community, the TAM has been improved in terms of increasing the number of constructs. Today, it is considered a TAM I, TAM II and TAM III model.

TAM has found application in many areas. For example, recent researches use this model as a starting point for investigating the adoption of new technologies such as m-learning (Al-Emran et al., 2018), food delivery applications (Song et al., 2021), investigating tea farmers' intention to participate in livestream sales (Doanh et al., 2022), adoption of artificial intelligence applications (Saif et al., 2024), etc. Moreover, the TAM can serve as a starting point for exploring the adoption factors of ERP systems (Sternad & Bobek, 2013; Limantara et al., 2021).

Therefore, this paper aims to investigate the attitude of SAP ERP system users towards the influence of the external variables of the TAM model on perceived ease of use. In this research, the focus is on the users of SAP ERP system as SAP is on the list of leading developers and providers of ERP solutions. Companies that use SAP's ERP system in their organization are highly valued in the global market. According to available data, these companies represent 98% of 100% of the world's most valuable brands. Many of these companies also operate on the territory of Serbia, where the research for this paper was conducted (SAP, 2024).

The contribution of this research lies in a deeper understanding of the attitudes of SAP ERP system users, especially by identifying the most important factors that influence their perceived ease of use (PEOU). The research results obtained provide valuable insights into the way users experience the SAP ERP system and identify key elements that may facilitate or hinder their use. This knowledge can serve as a basis for further improving the SAP ERP system, customizing it to users' needs and enhancing the user experience, which can lead to more efficient and productive operations in companies using this system.

The article is structured as follows. After an introduction, the second part deals with the literature review and the third part with the methodology. The methodology section explains the methods used, followed by a discussion of the results and concluding remarks.

2. LITERATURE REVIEW AND HYPOTHESIS DEVELOPMENT

TAM provides a theoretical framework for analyzing the adoption of new technologies, such as the SAP ERP system, and identifying factors that influence user perceptions (Cheng, 2015). In this research, the external variables of the TAM concept are of key importance. There are several different theories on which technology acceptance is based and therefore there are different views on which external variables should be included in the TAM concept when it comes to ERP systems.

A study by Chang et al. (2008) examined the influence of organizational factors (facilitating conditions and social factors), individual factors (short-term consequences, long-term consequences and affect) and technological factors (complexity and compatibility).

Putri et al. (2020) investigated the influence of three factors on the implementation of an ERP system in a distribution company. The factors related to top management support, training and technological complexity. Other research used other external variables such as factors related to user training, non-technological complexity and trainer support (Limantara et al., 2021).

This paper used external variables for SAP ERP solution adoption proposed by Sternad et al. (2019) related to system complexity, system performance, user guidance, social impact, and system complexity. A more detailed explanation of these variables can be found below.

2.1. System Complexity (SC)

Similar to other information systems, the ERP system has often been perceived as complex to understand and continue to use. System complexity can be defined as the degree to which the new technology is more complicated for the user than the previously used technology to perform the same or similar activities (Rajan & Baral, 2015). It also refers to the degree of complexity of the technology used by the customer and the level of difficulty and volume of transactions processed in information systems (Tahriri & Afsay, 2021). Ghallab et al. (2021) point out that the complexity of ERP systems can negatively influence users' attitudes towards using the system. This can be explained by the fact that the complexity of the SAP ERP system may require more time to master SAP and that the uncertainty and fear of making mistakes when working in SAP can lead to employee frustration. Since IS that are too complex to use are known to be difficult to accept at the same time (Chang et al., 2008), numerous studies have found that this external factor has a negative influence on PEOU. Therefore, this paper posits Hypothesis H_1: System complexity has a negative effect on perceived ease of use.

2.2. System performance (SP)

Marsudi and Pambudi (2021) confirmed that the performance indicators of companies improve after the implementation of IS thanks to the performance of the ERP system. On the other hand, research studies have demonstrated a significant relationship between the successful use of ERP systems and business performance. This means that the performance of the ERP system not only positively influences the perception of the ERP system, but also contributes to the overall efficiency of the company. If the system performs well, i.e. if it responds quickly to the customer's needs and ensures efficient execution of business tasks, users will consider the use of such a system to be meaningful (Al Shbail et al., 2024). Therefore, the following hypothesis is proposed H_2: System performance has a positive effect on perceived ease of use.

2.3. User manual (UM)

This external variable refers to written manuals in printed or electronic form, video manuals or other forms of information designed to help users effectively master the use of the SAP ERP system. An important segment after the implementation of the ERP system is the support provided by the ERP supplier, which is required in the form of guidance when harmonizing with new versions or updating existing functions or additions (Amado & Belfo, 2021). If there is good support in the form of user instructions, the degree of adoption of the ERP system is expected to be higher. Therefore, H_3 is proposed in this thesis: The user manual has a positive effect on perceived ease of use.

2.4. Social Impact (SI)

Social influence refers to the influence of social pressure and the opinions of influential people on a person to accept technology (Afsay et al., 2023). Previous research has shown that this factor plays an important role in the acceptance of new technologies, as the attitudes and values of the reference group to which a person belongs have an influence on the way a technology is accepted. In the research by AlMuhayfith and Shaiti (2020), organizational factors of top management support were found to have a significant impact on the success of ERP system adoption. If the social influence is positively oriented towards the use of the ERP system, then the individual's attitude towards the acceptance of the ERP system will also be positive

(Chang et al., 2008). This statement is followed by hypothesis H_4: Social influence has a positive effect on perceived ease of use.

2.5. Work Compatibility (WC)

This external variable can be explained as the match between people's values, experiences and needs and the new technology. Previous research has confirmed that compatibility has a positive effect on the constructs of the TAM model (Ozturk et al., 2016; Türker et al., 2022). Therefore, the following hypothesis is emphasized in H_5: Work compatibility has a positive effect on perceived ease of use.

Based on the theoretical review of the literature, a conceptual model was developed, which is shown in Figure 1.

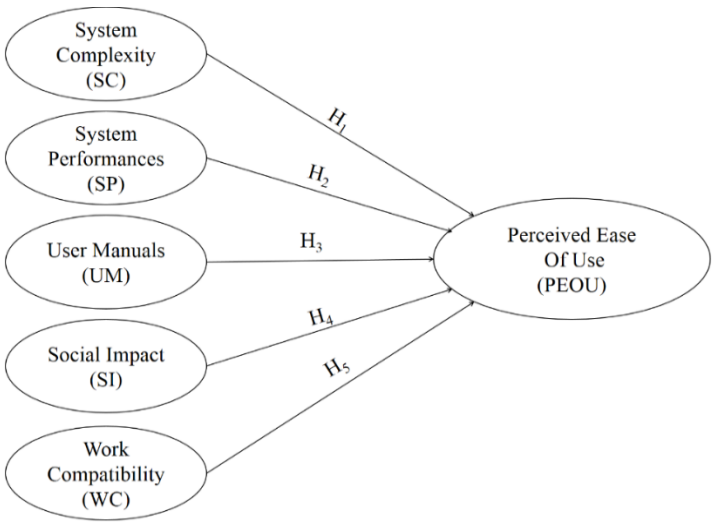

Figure 1. Conceptual model

3. METHODOLOGY

For this research, data was collected using an anonymous questionnaire based on the database of respondents created through the LinkedIn network, selecting respondents who work in the SAP ERP business software field. The survey was conducted in the second half of 2023. Of the 120 respondents to whom the questionnaire was sent, 94 answered all the survey questions in full. Respondents expressed their attitude using a five-point Likert scale, ranging from 1 (completely wrong) to 5 (completely right).

Structural equation modeling (SEM) was used to process the collected data and validate the hypotheses within the defined research model. SEM is a statistical method that can be used to test and analyze complex relationships between variables. SEM combines elements of factor analysis, regression analysis and path analysis to model complex relationships between manifest (directly measured) and latent (unmeasured) variables (Hsu et al., 2006). This methodology comprises two basic models: the measurement model and the structural model. The measurement model is assessed using reliability, convergence and discriminant validity tests (Sternad et al., 2019). The most commonly used reliability measures are Crombach's alpha test and composite reliability (CR). These indicators should have a value of more than 0.70. The most commonly used measures of convergent validity are the factor loadings, which should have values above 0.70, and the average variance extracted (AVE), which should be above 0.50. The so-called heterotrait-monotrait (HTMT) matrix is used to check the discriminant validity.

For the measurement model to be considered valid, the HTMT values must be below 0.90. When looking at variable measures, the coefficient of determination (R^2) is also considered, which determines the percentage of variance of the dependent variable (Hair et al., 2021). In this case, R^2 explains what percentage of the variance of the dependent variable PEOU is explained by the independent variables SC, SP, UM, SI and WC. The structural model confirms or rejects the hypotheses regarding the path coefficients. Path coefficients represent the standardized beta values (β) of the regression analysis. The SmartPLS ver. 4 software was used to apply the SEM modeling.

4. RESULTS AND DISCUSSION

Of the total number of respondents (94 in total) who participated in the survey and who are familiar with the SAP ERP business software, 60.6% are male and 39.4% are female. The predominant age category among the respondents is the 30-39 age group (50%), while the fewest respondents are 50-59 years old (4.3%). In terms of education level, most respondents have a Master's degree (46.8%) and the fewest respondents have a PhD (3%). The respondents were assigned to different positions, from HR specialists, team leaders, marketing specialists, analysts and the like. In the survey, there were no respondents from micro-organizations, which usually include entrepreneurial activities for which the SAP ERP system is not required.

4.1. Measurement model

The measurement model includes tests of reliability, convergent validity and discriminant validity. The results of the reliability and validity are shown in Table 1.

Table 1. Construct reliability and validity

Construct	Cronbach's alpha	Composite reliability	Average variance extracted (AVE)
PEOU	0.859	0.859	0.877
SC	0.773	0.773	0.688
SI	0.735	0.740	0.655
SP	0.886	0.889	0.689
UM	0.921	0.921	0.863
WC	0.922	0.923	0.865

Considering that all reliability indicators (Cronbach's alpha and CR) are above the recommended value of 0.70 and that the convergent validity indicator of the AVE model is above the recommended value of 0.50, the measurement model is considered suitable for further analysis based on these tests.

Table 2 shows the results of the HTMT matrix. From Table 2 it can be concluded that all values of the HTMT matrix are below 0.90, which is the maximum recommended value.

Table 2. HTMT matrix

	PEOU	SC	SI	SP	UM	WC
PEOU						
SC	0761					
SI	0.280	0.227				
SP	0.655	0.617	0.320			
UM	0.474	0.362	0.288	0.701		
WC	0.537	0.712	0.429	0.765	0.515	

Given that all indicators for the validity of the measurement model are within the recommended values, it is assumed that the evaluation of the structural model can be tackled.

4.2. Structural model

After the results were obtained using the measurement model, a structural model was applied and the results of the hypothesis tests are shown in Table 3.

Table 3. Results of tested hypotheses

Hypothesis		β	t statistics	p*	Result
H_1	SC → PEOU	-0.480	3.546	0.000	Supported
H_2	SP → PEOU	0.312	2.191	0.028	Supported
H_3	UM → PEOU	0.109	1.323	0.186	Rejected
H_4	SI → PEOU	0.075	0.926	0.354	Rejected
H_5	WC → PEOU	-0.104	0.640	0.522	Rejected

*significance level 0.05

Figure 2 shows the results of the structural model. Based on the research results, it can be said that SC has a negative and statistically significant influence on PEOU. Based on these results, hypothesis H_1 ($\beta = -0.480$; $p < 0.05$) was accepted. This was also confirmed by previous studies (Chang et al., 2008; Ghallab et al., 2021). SP has a positive and statistically significant influence on PEOU and thus confirms hypothesis H_2 ($\beta = -0.312$; $p < 0.05$). The constructs UM and SI have a positive but not statistically significant influence on PEOU, which rejects hypotheses H_3 ($\beta = 0.109$; $p > 0.05$) and H_4 ($\beta = 0.075$; $p > 0.05$). The same applies to hypothesis H_5, which was also rejected ($\beta = -0.104$; $p > 0.05$). All external factors mentioned explain a total of 49% (R^2) of the variability of the dependent variable PEOU. In the original study (Sternad et al., 2019), the R^2 indicator was 0.50, which indicates the consistency of the study results.

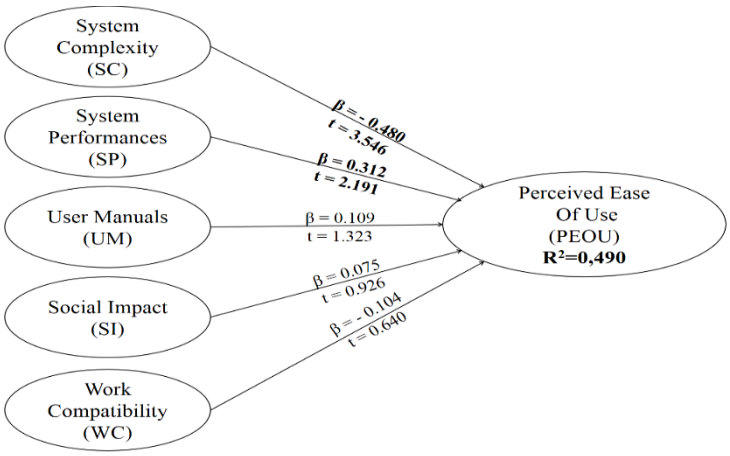

Figure 2. Structural model

5. CONCLUSION

The modern way of doing business is very different from the way organizations used to operate, and it is to be expected that the development of technologies and software engineering will cause such changes to continue. According to the available information, such changes are also taking place in Serbia, and it is not surprising that a large number of both large and small and medium-sized enterprises are switching from the traditional to the modern way of doing business due to the numerous advantages of using the ERP system. This paper presents the

results of an empirical study of a sample of SAP ERP system users from Serbia. The model examines the influence of external factors SC, SP, UM, SI and WC on PEOU as one of the basic constructs of the TAM model.

The research model was validated using the PLS structural modeling technique. The results show that out of the five external factors considered, only two factors have a statistically significant impact on PEOU, namely system complexity and system performance. When it comes to SAP ERP software, which includes complex information systems for enterprise resource planning, the complexity of the system can be an indicator of the richness of the functions that the software provides. If the software can perform a variety of complex tasks and processes, users may see this complexity as an indicator of powerful tools and features available to them. In this regard, users may perceive the software as user-friendly as they can perform a variety of tasks in one place. In addition, respondents believe that the high performance of the SAP ERP system, such as responsiveness, reliability and efficiency, contributes to its use. When a system responds quickly to user requests and performs tasks reliably, users view this efficiency as an indicator of ease of use. Faster and more efficient completion of user requests can make users' work easier, which also contributes to a positive perception of the software's usability. Understanding these external variables can help researchers to analyze and interpret the research findings on SAP ERP system users' attitudes more accurately and suggest more effective strategies for the implementation and adoption of this system in organizations. Despite some contribution, this research has its limitations. The first limitation relates to the sample size, which is insufficient to draw general conclusions. Therefore, a larger number of users of the SAP ERP system will be included in future research. The next limitation refers to the fact that only respondents from Serbia were included, as well as the fact that the respondents come from different fields of activity and different sizes of organizations in which they work. To overcome this limitation in future research, the sample should be expanded to other countries that have similar socio-cultural characteristics and the research should focus on only one type of industry to gain a more detailed insight into users' attitudes. In addition, the agenda of future research should aim to broaden the base of respondents, i.e. increase the sample size and test other ERP solutions available on the market.

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THE IMPACT OF KNOWLEDGE MANAGEMENT ON CORPORATE SUSTAINABLE DEVELOPMENT (CSD): THE MEDIATING ROLE OF GREEN INNOVATION

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Abstract: It is logical to assume that knowledge, as the most valuable resource in an organization, has an important role in achieving the goals of corporate sustainable development (CSD). However, not many studies have tried to uncover the true relationship between knowledge management practice and CSD. In that sense, this study aims to analyze the connection between these two variables. The study was conducted during the first quarter of 2024. The sample size used for the analysis consists of 84 managers from different hierarchical levels employed in Serbian companies which have already implemented knowledge management principles. The Partial Least Squares Structural Equation Modeling (PLS-SEM) technique is adopted to explore complex relationships among variables. In addition, the mediation analysis was performed to investigate the mediating role of green innovation practice in the relationship between knowledge management and CSD. The results suggest that the total effect of knowledge management on CSD is significant ($\beta = 0.670$, $p = 0.000$), indicating a positive relationship between these variables without considering the mediator. When mediator green innovation was included, the direct effect of knowledge management on CSD became very low and statistically insignificant ($\beta = 0.022$, $p = 0.934$), suggesting that the variable green innovation fully mediates the relationship between them.

Keywords: Knowledge Management, CSD, Green innovation, PLS-SEM.

1. INTRODUCTION

In today's globalized environment, with constant changes (social, economic, technological and environmental), in which the focus is on performance and success in the competitive advantage, organizations, in addition to focusing on the needs of customers, also

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focus their orientation on knowledge management and the development of employees' competencies. Furthermore, to meet customers' needs and achieve sustainable development (SD) goals, organizations adopt multiple strategies based on innovation and knowledge management (KM). Therefore, the success of an organization depends on the knowledge management (KM) infrastructure, which is the combination of people, processes and technology. Effective KM enables the company to be more innovative and effective (Yusr et al., 2017). For this reason, knowledge and KM have received significant attention in the business world and have been acknowledged as a vital element in designing strategies and developing new products and services (Mardani et al., 2018), which enables organizations to enhance customer satisfaction (Attia & Salama, 2018).

Nowadays, organizations adopt business practices which ensure sustainable development (SD) (Davenport et al., 2019) due to facing natural resource depletion and increasing global warming (Albort-Morant et al., 2018). According to Wijethilake (2017), SD has three aspects – environmental sustainability which place emphasis on the natural environment and resources, social sustainability relates to society and people, and economic sustainability focuses on the economic and financial aspects of firms (Guerrero-Villegas et al., 2018). For this purpose, for SD objectives to be achieved, firms must focus not only on technological innovation but also on green innovation. Green innovation is a concept that aims to help firms develop environmentally friendly products (Xie et al. 2019).

Mardani et al. (2018) and Davenport et al. (2019) highlighted the importance for more research on KM, green innovation and corporate sustainable development (CSD). Although many researchers have studied KM and SD from different perspectives, insufficient attention has been put to exploring the role of KM in achieving SD, particularly with the help of green innovation (Lim et al., 2017).

Therefore, this study will try to fill the gap in the literature by studying the relationship between KM practice and CSD in large- and medium-sized enterprises in the Republic of Serbia. In addition, the mediation analysis will be performed to investigate the mediating role of green innovation practice in the relationship between KM practice and CSD.

2. LITERATURE REVIEW AND HYPOTHESES

2.1. Knowledge Management (KM)

Knowledge is an intangible but valuable resource with two forms, explicit and tacit knowledge (Bolisani & Bratianu, 2018), which organizations use to compete successfully in the market (Mothe et al., 2018). Explicit knowledge is any knowledge that can be codified, transferred, and articulated (Ooi, 2014). Tacit knowledge is hidden and unwritten knowledge which exists in people's minds (Maravilhas & Martins, 2019). It is gained with experience, and it isn't easy to be shared among people (Johnson et al., 2019). According to Drucker (1995), knowledge is the most vital economic source for achieving a competitive advantage. Regarding that, KM is considerable in management circles because of its capability to provide organizations with strategic outcomes related to profitability, competitiveness, and capacity development (Oluikpe, 2012). The main objective of the KM process is to ensure vital information (knowledge) is properly identified, selected, organized, shared and used to help a firm perform its operations and achieve its objectives (Naicker et al., 2017). Bhatt (2001) defined KM as a process of creating, validating, presenting, distributing and applying knowledge. As for Ooi (2014), KM is a process through which organizations ensure their employees have the right information in the right format at the right time.

2.2. Sustainable Development (SD)

SD as a concept was first presented at the United Nations General Assembly in 1987 (Holden et al., 2014). In 1992, the third approach, social sustainability, was revised to SD (Munasinghe, 1992). Hence, the overall aim of CSD is to achieve economic, social, and environmental sustainability by integrating all approaches in the decision-making process. Therefore, the United Nations Global Compact (UNGC) has urged all businesses, particularly those in manufacturing, to follow environment-friendly processes and benefit from the latest technologies to utilize resources efficiently (UNGC, 2018). The environmental approach of SD focuses on preserving the natural environment, ensuring clean water and air, less consumption of natural resources, the production of environment-friendly products, and the reduction of dangerous gases and liquid emissions (Lucas, 2010). The social aspect of SD concentrates on enriching organizational relationships with human and society and promotes human well-being by understanding their needs (Guerrero-Villegas et al., 2018). It also aims to promote social and cultural life and ensure social development, social equity, human and labour rights, social support and justice. The economic approach of organizational SD relates to maximizing profit by increasing sales and reducing operational costs (Abbas & Sagsan, 2019).

2.3. Green innovation (GI)

Through green innovation, organizations eliminate or minimize the negative impact of their operations on the environment (Fernando et al., 2019). It represents the innovation in products, processes, technologies and management structures that aim to protect the natural environment (Li, et al., 2017) by minimizing resource consumption and controlling waste and pollution (Rossiter & Smith, 2018). Siva et al. (2016) and GY Qi et al. (2010) classified green innovation into two categories: green technology innovation (GTI) and green management innovation (GMI). GTI, helps firms to introduce new or improved existing products or processes that help to save raw materials, energy, and resources and develop harmony between the environment, economy, and production processes (Fernando et al., 2019). The GMI represents the firms' adoption of new management structures, systems and strategies to improve production processes (Li et al., 2018). Xie et al. (2019) further divided GTI into green process and green product innovation. Green process innovation aims to improve production processes by converting raw materials into a usable product (Albort-Morant, 2016). Green product innovation focuses on modifying existing product designs or developing new products that use renewable or non-toxic material in the production process so that energy efficiency can be achieved and the disposal impact on the environment can also be reduced (Zhang et al., 2019). Such management system enable firms to gain economic benefits and ensure minimization of environment hazardous activities (Siva, et al., 2016).

In the knowledge-based society, the relationship between KM and SD has become particularly important as, according to Maravilhas & Martins (2019), knowledge is the main driving force for individual, organizational, and national development. KM activities are the resources which enable firms to develop new technologies (Habib et al., 2019). Organizations use such technologies to develop new or improve existing products and processes so that organizational performance can be enhanced not only from economic perspectives but also from environmental and social perspectives (Stanovcic et al., 2015). Shahzad et al. (2020) said that organizational knowledge absorptive capacity significantly impacts their environmental performance.

KM is important in innovation processes as it provides a foundation for research and analysis (Sesay et al., 2018). Breznik (2018) analyzed the impact of KM on organizational

innovation and concluded that it triggers a firm's innovation activities. Several managers believe that innovation activities mediate the relationship between organizational social sustainability and organizational performance (Guerrero-Villegas et al., 2018). Abbas & Sagsan (2019) pointed out that KM and green innovation significantly impact CSD activities. Ghorbani (2023) found that companies which effectively manage their green knowledge can develop innovative solutions that address environmental challenges while achieving sustainable growth. Albloushi et al. (2023) showed a significant influence of TQM on CSD and green innovation. Also, green innovation positively affects CSD and fully mediates TQM and CSD relationships. Shahzad et al. (2020) found a significant positive impact of CSR on environmentally sustainable development.

Further, environmentally sustainable development positively enhances green innovation. The study revealed a positive influence of KM on GI and CSD. Rasheed et al. (2023) found a significant impact of KM practices on green innovation and sustainable growth. Koshelieva et al. (2023). emphasized the crucial role of KM in driving environmentally responsible practices and sustainable development.

Therefore, based on the previous literature review, the following hypotheses are proposed:

H1. KM has a positive and significant impact on CSD.
H2. KM has a positive and significant impact on green innovation (GI).
H3. Green innovation has a positive and significant impact on CSD.
H4. Green innovation as a mediating variable increases the effect of KM on CSD.

The empirical and conceptual evidence presented above suggests that the KM process can improve CSD directly or indirectly mediated by green innovation. Based on these arguments and according to the above-proposed hypotheses, the conceptual model was developed, as shown in Figure 1.

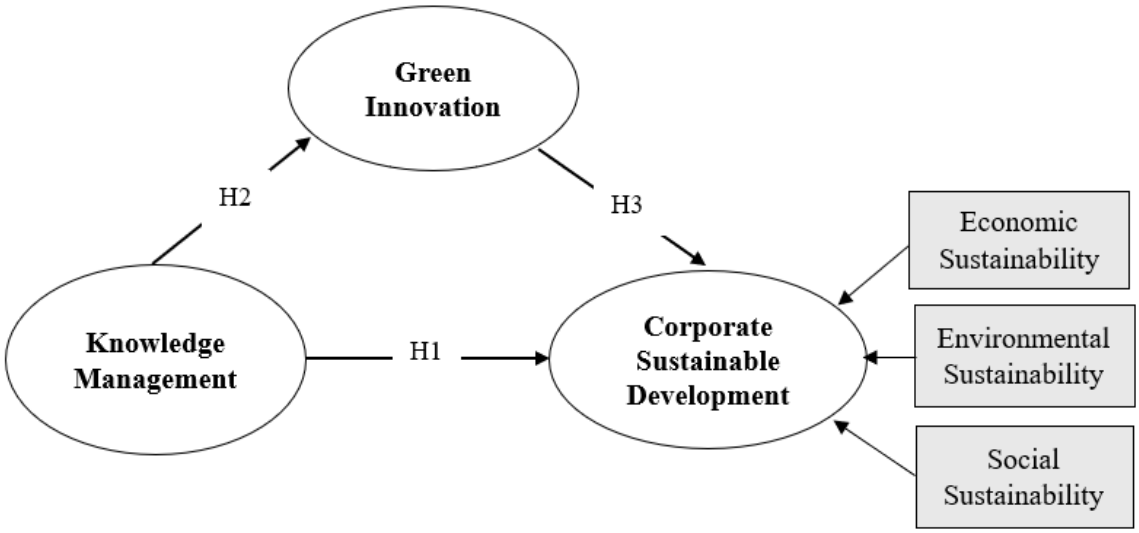

Figure 1. Conceptual model

3. DATA AND METHODOLOGY

The main purpose of this study was to analyze the impact of knowledge management (KM) practice on corporate sustainable development (CSD), with the mediating effect of green innovation (GI). The sample consists of managers on different hierarchical levels who work in organizations that have already implemented KM principles. Data were collected during the

first quarter of 2024 and included 84 managers. The authors conducted the research personally using online Google Forms.

Table 1. Socio-demographic characteristics of the sample (n=84)

Variables	Category	Frequency	Share (%)
Type of industry	Manufacture	62	73.8
	Service	22	26.2
Size of organization	Medium	34	40.5
	Large	50	59.5
Job position	Top management	35	41.7
	Middle management	32	38.1
	Operative level management	17	20.2
Gender	Male	55	65.5
	Female	29	34.5
Years of employment	≤5	13	15.5
	6-10	32	38.1
	11-15	18	21.4
	≥16	21	25.0

Demographic characteristics (Table 1) showed that the statistical population included mostly male top managers working in manufacturing large-sized organizations with 6 – 10 years of working experience.

The questionnaire was designed and modified based on the questionnaires from similar studies (Lee & Wong, 2015; Wong, 2013; Kam-sing Wong, 2012; Turker, 2009; Wang et al., 2008; Bansal, 2005; Darroch, 2003) and it contained 45 questions. The first 5 questions focused on the general characteristics of the organization (industry, size) and respondents (gender, position and working experience). The remaining 40 questions were divided into three groups: Knowledge management – 21 questions; Green Innovation – 7 questions; and Corporate Social Development – 12 questions. A five-point Likert scale was used to evaluate the respondents' answers, ranging from 1 (completely disagree) to 5 (completely agree).

The Partial Least Square (PLS) approach to Structural Equation Modelling (SEM) was used to analyze the relationship between the observed variables. One of the main reasons why PLS-SEM was chosen in this study is that PLS-SEM is very suitable for small sample analysis (Henseler et al., 2015). The modelling process is divided into two main stages: Stage 1 - Measurement Model Assessment and Stage 2 - Structural Model Assessment. The measurement model reflects the interactions between the observed data and the latent variable, whereas the structural model represents the relationships between latent variables. In addition, we have also analyzed the mediating role of the green innovation (GI) process in the relationship between KM practice and corporate social development (CSD).

4. RESULTS AND DISCUSSION

4.1. Measurement Model Assessment

Measurement model assessment included establishing construct reliability and validity of scale tools (Huang et al., 2021). The construct reliability and convergent validity of the measurement model are assessed using Cronbach's alpha (CA), rho A, Composite Reliability (CR), and Average Variance Extracted (AVE), which are presented in Table 2.

Table 2. Construct reliability and validity

Construct	Cronbach's alpha	rho_A	CR	AVE
CSD	0.962	0.966	0.963	0.684
GI	0.947	0.949	0.947	0.690
KM	0.960	0.963	0.959	0.531

According to Table 2, both Cronbach's Alpha and CR values exceed the recommended threshold of 0.70, as suggested by Hair et al. (2017). The obtained Cronbach's Alpha values ranged from 0.947 to 0.962, indicating satisfactory internal consistency for all the constructs. Furthermore, the CR ranged from 0.947 to 0.963, providing further support for the reliability of the constructs. Convergent validity is assessed using the Average Variance Extracted (AVE) statistic. As Fornell and Larcker (1981) recommended, an AVE value equal to or greater than 0.50 indicates that the items converge to measure the underlying construct, thus establishing convergent validity. In this study, the AVE value for the constructs was higher than 0.5, so convergent validity is also confirmed (Hair et al., 2017).

Besides convergent validity, the discriminant validity should also be checked before assessing the structural model. Henseler et al. (2015), suggested the usage of the Heterotrait-Monotrait ratio of correlations (HTMT) criterion for that purpose. According to Kline (2011), a threshold value needs to be 0.85 or less, while other authors, Franke and Sarstedt (2019), proposed a threshold of 0.90 or less.

Table 3. Discriminant validity—HTMT ratio

Construct	CSD	GI
CSD		
GI	0.891	
KM	0.661	0.726

Table 3 indicates that all HTMT ratios are lower than the suggested threshold of 0.9 (Franke and Sarstedt, 2019; Henseler et al., 2015), confirming the good discriminant validity of the model.

4.2. Structural Model Assessment

Since the reliability and validity of the measurement models are established, hypothesized causal relationships within the inner model can be evaluated using PLS-SEM. The hypotheses were tested in a two-tailed manner, specifically emphasizing the positive direction of the relationships. To assess the statistical significance of these relationships, the bootstrapping procedure in SmartPLS4 software (5000 bootstrap samples were generated) was employed (Ringler et al., 2022).

Table 4. Results of the structural model assessment – direct effect

Hypothesis	*β*	SD	*t*	*p*	Results
H1: KM -> CSD	0.022	0.270	0.083	0.934	Not confirmed
H2: KM -> GI	0.740	0.105	7.078	0.000*	Confirmed
H3: GI -> CSD	0.875	0.249	3.514	0.000*	Confirmed

β – path coefficient, SD – standard deviation, *p* – level of significance lower than 0.000

The obtained results (Table 4) show that the path coefficient indicating the relationship between KM practice and CSD is very low (*β*=0.022) and statistically insignificant (*p*=0.384), suggesting that hypothesis H_1 should be rejected. However, positive and statistically significant path coefficients between variables knowledge management and green innovation (*β*=0.740,

p=0.000), as well as between green innovation and CSD (*β*= 0.875, *p*=0.000), support hypotheses H_2 and H_3.

The mediation analysis is also performed to investigate the mediating role of green innovation in the relationship between KM practice and CSD in observed organizations. The results shown in Table 5 reveal that the total effect of KM on CSD is significant (*β* = 0.670, p = 0.000), indicating a positive relationship between these variables without considering the mediator. When mediator green innovation was included, the direct effect of KM on CSD became very low and statistically insignificant (*β* = 0.022, *p* = 0.934), suggesting that the relationship between them is fully mediated by the variable green innovation (GI), which confirms hypothesis H_4.

Table 5. Total effect, direct effect, and indirect effect for the model mediation

Construct	Total effects			Direct effects			Indirect effects				
KM > CSD	*β*	*t*	*p*	*β*	*t*	*p*	*β*	*t*	*p*	Percentile bootstrap 95% CI	
										Lower	Upper
	0.670	4.813	0.000*	0.022	0.083	0.934	0.648	4.010	0.000	0.217	0.815

β = Path Coefficient, *t* = t-Statistics, *p* = level of significance *$p < 0.05$.

Finally, the evaluation of obtained R^2 (the coefficient of determination) and f^2 (the effect sizes of the paths) supplement the previous analysis (Table 6).

Table 6. R^2 and f^2 values

Predictor	Outcome	R^2	f^2
Knowledge Management (KM)	Green Innovation (GI)	0.543	1.213
Knowledge Management (KM)	Corporate Social Development (CSD)	0.791	0,001
Green Innovation (GI)			1.694

R^2 has been used to determine the explained variance of the latent dependent variables in relation to the overall variance. The cutoff R^2 values suggested by Chin (2009) are as follows: 0.190 weak, 0.333 moderate, and 0.670 substantial. According to the results in Table 6, the overall model explained 79.1% of the variance in CSD. The model also explained 54.3% of the variance in variable green innovation, so it can be said that some other factors influence this variable, but the model has a good predictive value.

Value f^2 measures the strength of each predictor variable in explaining endogenous variables. An f^2 value from 0.02 to 0.149 is considered small, from 0.15 to 0.35 is considered medium, and higher than 0.35 is considered large, according to Cohen (1988). Considering these thresholds, a large effect was found in the relationship between KM and GI, as well as GI and CSD, 1.213 and 1.694, respectively. On the other hand, no effect was recorded in the relationship between KM and CSD.

4.3. Discussion

KM has gained considerable attention from the business sector in the last couple of decades. They understand very well the true value of knowledge in achieving and keeping a competitive advantage. In the meantime, considering the environmental challenges, dynamic

firms have expanded the KM scope and have started integrating the environment into it. Effective KM practice is expected to help organizations achieve green innovation concepts and sustainability goals.

The results obtained in this research indicate that knowledge management practice doesn't directly affect corporate sustainable development, which is opposite to other studies (Abbas & Sagsan, 2019; Lutchen, 2018; Chen et al., 2015). The positive and significant total effect between KM and CSD, as well as the positive and significant indirect effect between KM → GI → CSD, suggest that this relationship is fully mediated by green innovation.

Unfortunately, the obtained result indicates that the sampled firms in Serbia are not using their knowledge resources efficiently and that their management is not demonstrating a strong commitment to KM by motivating their employees to create, acquire, share and apply knowledge in their work to achieve SD objectives.

However, the positive impact of KM on GI suggests that studied organizations recognize the importance of green innovation practices, so they are using their knowledge to create products and processes which are more environmentally friendly. These could help them to achieve not just environmental goals but also economic and social goals by targeting those customers who are environmentally aware. Similar results were obtained by Wang et al. (2022); Song et al. (2022). They explained that the ability of organizations to manage green knowledge is directly related to their green innovation capabilities. However, the biggest problem is how to manage green knowledge.

The results also confirmed a positive relationship between green innovation (GI) and CSD. In their work, Ahmed et al. (2022), and Abbas and Sağsan (2019) reported the same results. According to them, green innovation significantly influences organizations' financial and environmental performance. By introducing green technologies and products, organizations could improve their chances of achieving sustainable development goals successfully. Ardito et al. (2019) stated that organizations that adopt green innovation practices have bigger chances to attract more consumers and, in that way, achieve their economic goals. Interestingly, some studies have analyzed the opposite direction of this relationship by investigating the impact of CSD on GI. Shahzad et al. (2021), and Saunila et al. (2018) recognized that the social dimension of sustainability positively influences green innovation exploitation and investment.

5. CONCLUSION

The concepts of KM and CSD are very well explained in the literature. However, not many studies regarding their relationship have been conducted in transition economies since their implementation is still in the beginning stages. The findings of this research shed light on the intricate relationship between KM, green innovation, and CSD. While some prior studies have suggested a direct link between KM and CSD, the results here indicate that this relationship is fully mediated by GI, highlighting the crucial role of green innovation in achieving sustainable development objectives.

In that sense, it can be said that the theoretical contribution of the research is in filling these gaps with the results for transition countries. The research highlights the evolving nature of KM practices, with organizations recognizing the importance of integrating environmental considerations into their KM strategies. This underscores the need for theoretical frameworks that incorporate environmental dimensions into traditional KM models. The practical implication for managers (especially in studied organizations) could be that they need to make more effort to create a culture that promotes and supports KM if they want to achieve sustainable development goals. Fostering a culture of knowledge sharing, enhancing green

innovation capabilities, and embracing sustainable practices can pave the way for achieving long-term corporate sustainability goals.

This research also has several limitations. The first limitation is reflected in the fact that only a few companies from Serbia were included in the study, so the results can't be generalized. The second CSD scale was based on respondents' perceptions and evaluations, which may be subject to bias and measurement error. Future research will try to expand the sample and cover all these limitations.

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THE ROLE OF STANDARDISATION IN THE ADOPTION OF ARTIFICIAL INTELLIGENCE IN THE WORKPLACE

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Abstract: Integrating Artificial Intelligence (AI) into the workplace is imperative for navigating the challenges and opportunities of the fifth industrial revolution. In recent years, bringing AI and related technologies into the workplace has increased productivity, cost efficiency and work performance. Still, these changes in the work environment raised issues such as dehumanisation, lack of employee trust, and high job insecurity, leading to difficulties in AI adoption. At the same time, there are many standardisation activities in the field of AI, such as security standards, ethical guidelines, interoperability protocols, and others. However, it is believed that standardisation endeavours are still not close to the number of developed solutions that use AI technology. The problem analysed in this research is the role of standardisation in adopting AI in the workplace. To investigate this relationship, data was collected using a survey developed based on OECD research on the impact of AI and an extensive literature review. To answer the raised question, the research focus will be on exploring the impact of company and employee characteristics on the perceived role of standardisation in adopting AI in the workplace. As statistical tools, descriptive statistics and hypothesis testing will be used. It is believed that this research will give insights into whether companies and their employees recognise standardisation and standards as tools for adopting AI in the workplace to ensure interoperability, trustworthiness, and safety and security of AI solutions.

Keywords: standardisation, artificial intelligence, workplace, hypothesis testing

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1. INTRODUCTION

The integration of AI in the workplace presents both opportunities and challenges. AI has the potential to enhance individual and organisational learning, improve productivity, and automate low-value HR tasks (Wilkens, 2020; Badhurunnisa & Sneha Dass, 2023; Kaur et al., 2023) . However, it also raises concerns about job displacement, ethical implications, and the need for responsible AI integration (Badhurunnisa & Sneha Dass, 2023; Kaur et al., 2023). Worker perspectives on AI in office workspaces are complex, with a focus on communication, privacy, and the potential benefits for health and behaviour change (Fukumura et al., 2021). The acceptability of AI in the workplace is contingent on its ability to accommodate individual needs (Fukumura et al., 2021).

Simultaneously, substantial standardisation endeavours in AI encompass data standards, interoperability protocols, ethical guidelines, and others (Ziegler, 2020). Despite these efforts, the role of standards in facilitating AI adoption in the workplace remains largely uncharted territory. A pressing question persists: Can standardisation and standards serve as tools to bolster AI adoption in work settings? To shed light on this inquiry, employees' perspectives across various industries and their perceptions regarding the role of standardisation and standards in AI adoption will be analysed. Further, it will be explored whether there are differences among European Union (EU) and non-EU regions regarding the perception of standardisation and standards as tools for adopting AI at the workplace.

After the introduction in which the issue of AI adoption in the workplace is outlined amidst the rise of standardisation efforts in this field, the author examines the existing literature on their interplay in the following section. Section three presents the research methodology alongside the applied statistical method. The following section gives insight into sample structure and the results of the conducted hypothesis testing. The final two sections are devoted to the study's discussion, conclusion, and future directions.

2. LITERATURE REVIEW

The adoption of AI in various industries has been a key focus of recent research. AI has been found to enhance operational efficiency, improve decision-making, and provide real-time insights and analytics (Abousaber & Abdalla, 2023). In marketing, AI has transformed processes and is expected to continue doing so in the future (Jabeen, 2022). The potential impact of AI on various industries, including healthcare, education, and manufacturing, has been highlighted, with a call for increased investment in emerging markets (Mou, 2019). The application of AI in different industries, such as telecommunications, has been shown to provide added value and improve competitiveness (Makar, 2023).

The adoption of AI in the workplace is influenced by various factors, including employees' trust in the technology. Chaudhry and coauthors (2022) found that employees' generation, knowledge, and skills significantly impact their trust in AI and subsequent adoption of the technology. However, Vogel and coauthors (2023) noted that employees without AI experience tend to reject the technology due to fear of consequences, highlighting the need for increased AI understanding. Lockey and coauthors (2020) emphasised the importance of trust in AI, with findings expressing low trust in AI systems but generally accepting or tolerating them. In order to bolster trust in AI among companies and foster wider acceptance of the technology, it is imperative for companies to adhere to the principles of trustworthy AI and strenghten the regulatory framework. Wang and Siau (2018) highlighted the potential threats posed by AI, such as data breaches and unemployment, which can hinder trust and acceptance

of the technology. Still, AI researchers and the organisations that employ them are uniquely positioned to shape the landscape of AI-enabled products and services (Brundage et al., 2018). Vogel and coauthors (2023) underscore the role of employee acceptance and expertise in successful implementation.

The integration of AI into workplace environments faces obstacles due to a deficiency in trust, a challenge that can be overcome through the creation of AI solutions that are both trustworthy and ethically sound (Vianello et al., 2023). The trustworthiness of AI is a critical concern, particularly in applications that impact human lives (Jain et al., 2020). This trustworthiness can be achieved through a combination of product and organisational measures, including AI-specific risk analysis and an AI management system (Schmitz et al., 2022). Responsible AI requires a focus on both trustworthy computing and formal methods (Wing, 2021). The safety and security of AI is a critical concern, particularly in the context of AI hardware systems (Shen, 2021). Humans' role in mitigating AI risks in cybersecurity is also emphasised (Oche, 2019). It is suggested that AI security should be carefully designed, with a focus on data security and assurance processes (Puthal & Mohanty, 2021). The interoperability of AI is a crucial aspect of its development and deployment, with various strategies and levels of interoperability being proposed. Sarkadi and coauthors (2022) emphasise the importance of translation-based approaches and the need for incentives to support them. Thai and Tong (2019) discussed the need for interoperability standards in adaptive instructional systems, proposing extensions to current industry standards. Sarkadi and Gandon (2023) further explores the concept of self-organising AI agents and their potential communication strategies.

At the same time, there are many standardisation activities in the field of AI. Standardisation efforts concerning AI are currently underway at the International Organization for Standardization (ISO) in collaboration with the International Electrotechnical Commission (IEC) and the Institute of Electrical and Electronics Engineers (IEEE), esteemed organisations dedicated to formulating international standards. These ongoing standardisation endeavours primarily address ethical considerations and strategies for enhancing market efficiency (Cihon, 2019; Mijatović et al., 2023). At the European level, standardisation work on AI is underveyed by the European Telecommunications Standards Institute (ETSI). Wang and coauthors (2018, 2020) discuss ETSI's work in the area of network management and orchestration using AI, mainly through the Industry Specification Group on Experiential Networked Intelligence (ENI). Numerous standardisation endeavours in the AI domain are acknowledged, yet they require refinement in light of the growing number of developed solutions and applications utilising AI technology (Ziegler, 2020). Standards play a pivotal role in shaping the development and implementation of specific AI systems, encompassing product specifications such as explainability, robustness, and fail-safe design (Cihon, 2019). Consolidating efforts to address diverse AI aspects into a unified system is challenging, but a landscape of AI Standards emerges as a solution. This landscape constitutes an analysis of standardisation activities within the AI domain, encompassing a compilation of standards and ongoing international efforts across active standardisation organisations (Ziegler, 2020). However, potential overlaps arise due to divergent definitions and understandings of AI features, complicating efforts to regulate pertinent aspects and determine regulatory responsibility. Moreover, numerous initiatives progress slower than AI solutions, prompting consideration of the opportune moment for AI developers to engage in standardisation processes, which inherently demand greater participation proportional to the proliferation of AI solutions. Secondly, market dynamics necessitate understanding which industries adopt AI solutions, the regulatory demands confronting AI technology developers, and the intricate relationship between AI regulation and standards.

However, the role of standards in facilitating AI adoption in the workplace remains largely underexplored. It remains uncertain whether companies and their employees perceive standardisation and standards as tools for fostering AI adoption in the workplace, thereby ensuring interoperability, trustworthiness, and the safety and security of AI solutions.

3. DATA AND METHODOLOGY

A questionnaire inspired by the OECD's examination of AI's influence on the workplace was developed for research purposes. The questionnaire was administered digitally, targeting individuals engaged in AI-related professional communities on LinkedIn and reaching out to professionals across diverse industries susceptible to AI impacts. Participation was voluntary, and responses were treated confidentially. The sample comprised 222 participants from various corporate backgrounds.

The first part of the questionnaire was focused on participants' demographic details, encompassing gender, education level, employment status, job role, industry sector, primary region of employment (EU or non-EU), company type (national or multinational), and company size.

The second section of the questionnaire delved into the integration of AI within workplaces, drawing from insights outlined in the OECD's examination of AI's workplace impact (Lane et al., 2023). This section is initiated by acquainting respondents with the OECD's definition of AI to ensure a comprehensive grasp of the research investigation's scope. Participants were then queried about their company's AI utilisation and invited to elaborate on their company's acknowledgement of standardisation and standards as tools for AI adoption in the workplace. Further, we asked the respondents whether their company uses standardisation and standards to ensure the interoperability of AI systems, predictability, safety, and security, the trustworthiness of AI systems, to unify quality characteristics and technology platform requirements of AI systems, and if is it highly standardised workplace is more suitable for AI systems.

The focus of this research is on examining the role of standardisation and standards in the adoption of AI in the workplace. To investigate this relationship, two hypotheses were formulated:

Hypothesis 1 (H1): Variations exist among EU and non-EU regions concerning companies' perceptions of standardisation and standards as tools for AI in the workplace.

Hypothesis 2 (H2): Variations exist among companies across different industries regarding their perceptions of standardisation and standards as tools for adopting AI in the workplace.

For the analysis, the responses of respondents to the following questions were used:

1 To the best of your knowledge, does your company recognise standardisation and standards as tools for adopting artificial intelligence in the workplace?
2 To what extent do you agree or disagree with the following statements (On a scale 1-5)?
    a. At my company standardisation and standards are used to ensure the interoperability of AI systems.
    b. At my company, standardisation and standards are used to confirm AI systems' predictability, safety, and security.
    c. At my company standardisation and standards are used to ensure the trustwortiness of AI systems.
    d. At my company standardisation and standards are used to unify quality characteristics and technology platform requirements of AI systems.

e. Highly standardised workplace is more suitable for AI systems.

Descriptive statistics and hypothesis testing were used as statistical tools to test the defined hypotheses.

4. RESULTS AND DISCUSSION

A total of 222 respondents participated in the comprehensive survey, with males comprising 64% (142) and females 36% (80) of the sample. The survey primarily captured the younger working demographic, with the majority falling between the ages of 25 and 35 (73.4%), followed by those aged 35 to 49 (26.6%). The respondents demonstrated a high educational attainment, with 59.9% holding MSc diplomas, 28.4% holding BSc diplomas, and the remaining having either high school diplomas or PhDs. Employment status indicated that the majority were fully employed (92.3%), with 7.7% being self-employed. The sample displayed a somewhat balanced distribution between managerial (59.5%) and non-managerial (40.5%) positions held. In terms of industry representation, the highest proportion came from the IT sector (47.7%), followed by Sales (13.1%), Manufacturing and Logistics (12.6%), Finance Analytics (12.2%), Education/Academia/Research (8.6%), and Telecommunications (5.9%). Most respondents worked for multinational companies (69.8%) with over 500 employees (44.6%), primarily operating outside the EU region (70.3%).

Most of respondents (69%) answered yes to the question: To the best of your knowledge, does your company use artificial intelligence (AI)? Similarly, most of our respondents (49%) answered yes to the question: To the best of your knowledge, does your company recognise standardisation and standards as tools for adopting artificial intelligence in the workplace?

The Chi-Square test was employed to examine potential disparities between respondents holding managerial positions and those who do not regarding their perception on how companies recognise standardisation and standards related to AI. The analysis revealed no significant distinction in the perception workplace between these two groups (CrossTabs, Chi-Square 2.566, $p>0.05$). Additionally, a comparison between respondents occupying managerial positions and those who do not was conducted using the Mann-Whitney U test, assessing their alignment with statements concerning the utilisation of standardisation and standards in adopting AI systems. Across all conducted Mann-Whitney tests, significance levels exceeded 0.05, indicating no discernible difference between these two groups in their perception of how standards and standardisation are employed in adopting AI in the workplace.

Further, respondents from the EU and non-EU regions were compared using the Mann-Whitney U test regarding their agreement with statements about the use of standardisation and standards in adopting AI systems (Table 1).

For the item: "At my company standardisation and standards are used to ensure the interoperability of AI systems ", findings suggest a statistically significant difference between employee perceptions from the EU and non-EU regions ($MW=-2.875$, $p=0.004$). The conclusion is that respondents from the EU region are more likely to perceive that standardisation and standards are used to ensure AI systems' interoperability than non-EU respondents.

For the item:" At my company, standardisation and standards are used to confirm AI systems' predictability, safety, and security", findings suggest a statistically significant difference between the EU and non-EU regions ($MW=-2.143$, $p=0.032$). The conclusion is that respondents from the EU region are more likely to perceive that standardisation and standards

are used to confirm AI systems' predictability, safety, and security compared to non-EU respondents.

For the item: "At my company standardisation and standards are used to unify quality characteristics and technology platform requirements of AI systems", findings suggest a statistically significant difference between the EU and non-EU regions (MW=-2.100, p=0.036). The conclusion is that respondents from the EU region are more likely to perceive that standardisation and standards are used to unify quality characteristics and technology platform requirements of AI systems compared to non-EU respondents.

Table 1. Mann-Whitney U Test results for perception of the use of standardisation and standards in adopting AI systems

Question	Group	Mean ± Std	MW	P value
At my company standardisation and standards are used to ensure the interoperability of AI systems	EU	3.41±1.215	-2.875	.004
	NON EU	2.95±1.179		
At my company, standardisation and standards are used to confirm AI systems' predictability, safety, and security	EU	3.41±1.215	-2.143	.032
	NON EU	3.04±1.196		
At my company standardisation and standards are used to unify quality characteristics and technology platform requirements of AI systems	EU	3.32±1.242	-2.100	.036
	NON EU	2.99±1.147		

Further, respondents from different industries (IT industry, Sales, Manufacturing and Logistics, Finance analytics, Education/Academia/Research, and Telecommunications) in which they work were compared using the Kruskal Wallis test to determine their agreement with statements about the use of standardisation and standards in adopting AI systems (Table 2.).

For the item: "At my company standardisation and standards are used to ensure the interoperability of AI systems ", findings suggest a statistically significant difference between the IT industry, Manufacturing and Logistics, Finance analytics, and Telecommunications in opposition to Sales and Education/Academia/Research (KW=17.332, p=0.004). The conclusion is that respondents from the first four industries are more likely to perceive that standardisation and standards are used to ensure AI systems' interoperability than respondents employed in Sales and Education/Academia/Research.

For the item: "At my company, standardisation and standards are used to confirm AI systems' predictability, safety, and security", findings suggest a statistically significant difference between the IT industry, Manufacturing and Logistics, Finance analytics, and Telecommunications in opposition to Sales and Education/Academia/Research (KW=14.886, p=0.011). The conclusion is that respondents from the first four industries are more likely to perceive that standardisation and standards are used to confirm AI systems' predictability, safety, and security than respondents employed in Sales and Education/Academia/Research.

For the item: "At my company standardisation and standards are used to ensure the trustworthiness of AI systems", findings suggest a statistically significant difference between the IT industry, Manufacturing and Logistics, Finance analytics, and Telecommunications in opposition to Sales and Education/Academia/Research (KW=14.052, p=0.015). The conclusion

is that respondents from the first four industries are more likely to perceive that standardisation and standards are used to ensure the trustworthiness of AI systems than respondents employed in Sales and Education/Academia/Research.

Table 2. Kruskal Wallis Test results for perception of the use of standardisation and standards in adopting AI systems

Question	Group	Mean ± Std	KW	P value
At my company standardisation and standards are used to ensure the interoperability of AI systems	IT	3.08±1.204	17.332	.004
	Manufacturing and Logistics	3.36±1.162		
	Education	2.74±1.327		
	Finance analytics	3.48±1.156		
	Sales	2.45±1.088		
	TelCo	3.62±.870		
At my company, standardisation and standards are used to confirm AI systems' predictability, safety, and security	IT	3.23±1.237	14.886	.011
	Manufacturing and Logistics	3.50±1.291		
	Education	2.84±1.119		
	Finance analytics	3.37±1.115		
	Sales	2.45±1.121		
	TelCo	3.31±.751		
At my company standardisation and standards are used to ensure the trustwortiness of AI systems	IT	3.14±1.207	14.052	.015
	Manufacturing and Logistics	3.46±1.319		
	Education	2.79±1.134		
	Finance analytics	3.26±1.095		
	Sales	2.48±1.122		
	TelCo	3.54±.877		

5. CONCLUSION

The role of standardisation and standards in AI adoption is still unresearched, but AI will continue to change and shape workplaces in numerous industries. This research gave some insights into companies and their employees' perceptions regarding standardisation and standards as tools for adopting AI in the workplace to ensure interoperability, trustworthiness, and safety and security of AI solutions. Industries that use AI-based technology are dependent upon frameworks of standards, which constitute an infrastructure that extends from upstream activities such as R&D to the market. Both of the proposed hypotheses outlined in the research have been validated. The findings of this research acknowledged that respondents from the EU region are more likely to perceive that standardisation and standards are used to confirm, ensure, or unify AI systems' characteristics (predictability, safety, and security; interoperability) compared to non-EU respondents. Further, findings suggested that respondents employed in the IT industry, Manufacturing and Logistics, Finance analytics, and Telecommunications are more likely to perceive that standardisation and standards are used to confirm AI systems' characteristics than respondents employed. Those findings can be explained by the better employment of AI in the first four industries than in sales and Education/Academia/Research.

Although the presented study illuminates the significance of standardisation and standards in integrating AI within workplace environments, it is imperative to interpret the research findings mindful of their limitations. Notably, the analysed sample encompasses only 222 respondents. Expanding the sample size would enhance the generalizability of the results. Strategies to augment the sample could involve conducting a large-scale survey within Serbia

or extending the research scope to encompass neighbouring countries like Croatia, Slovenia, Bosnia, or Montenegro.

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THE RESILIENCE OF ITALIAN AND POLISH FAMILY ORGANIZATIONS: A COMPARATIVE STUDY USING FSQCA

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Abstract: This study endeavours to investigate the impact of economic contexts on the resilience strategies adopted by family businesses in Italy and Poland. Through a comparative analysis of these two countries' family-owned enterprises, the research aims to elucidate the divergent approaches to achieving organizational resilience amidst varying economic landscapes, thereby uncovering the underlying mechanisms driving resilience in both developed and transitioning economies. Drawing on data collected from 30 Italian and 30 Polish companies, this study examines the similarities and differences in the configurations of past firm performance, organizational unlearning, slack resources, innovation, and environmental dynamism, employing the fsQCA approach. The findings highlight distinct patterns in the factors shaping organizational resilience within each context. In Italian companies, the study reveals that heightened organizational resilience is primarily linked to the ability to discard outdated processes through effective organizational unlearning, alongside the presence of ample slack resources. Conversely, in Polish companies, a multifaceted approach encompassing adaptability to dynamic environments, effective unlearning practices, innovation initiatives, and a history of strong past performance emerges as crucial for fostering resilience.

Keywords: Organizational resilience, comparative study, Poland, Italy, FSQCA

1. INTRODUCTION

Over the last decade, significant shifts have reshaped the global economic and business landscape, marked by challenges like terrorism, political turmoil, cyber threats, and more recently, the Covid-19 pandemic (i.e. Schwaiger, Zahrer & Braun, 2022). These events have underscored the inadequacies of conventional control systems, which, while effective in maximizing profits during stable phases of business growth, often prove ineffective or even detrimental in times of crisis (Beuren, Santos, & Bernd, 2020).

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This study aims to contribute to the ongoing discourse on the nexus between family-owned businesses, family involvement, and performance. Family businesses are often portrayed as resilient entities capable of weathering economic storms with perseverance and skill. Unlike conventional businesses, they are seen as possessing a unique autonomy that enables them to navigate crises adeptly (Amann & Jaussaud, 2014). Crisis management is defined by the British Standards as the strategies employed when managerial capabilities are stretched beyond their limits in the face of abnormal and destabilizing situations.

Today's management control systems must acknowledge that crises are not aberrations but integral aspects of business and corporate life. Rather than fixating on predicting crises, attention should be directed towards monitoring of internal and external environments. Strategic crisis management, along with its associated tools, emerges as a source of competitive advantage for those who embrace it. Managers must foster a culture of resilience and adopt innovative practices to adapt and strengthen their positions, contrasting with those who adhere to traditional methods and risk being phased out of the market.

Family businesses, particularly during crises, often display behaviors geared towards ensuring the survival and continuity of the enterprise across generations, facilitated by their stewardship ethos and the unique resources they possess, known as "familiness" (Beech et al., 2020). This study seeks to explore how economic specificity influences the resilience strategies of family businesses in Italy and Poland. By comparing Italian and Polish family businesses, it aims to delineate the disparities in how organizational resilience is achieved across varied economic contexts, shedding light on the mechanisms through which resilience is attained in developed and transitioning economies.

The methodology employed involves a fuzzy-set qualitative comparative analysis based on data collected from 30 Italian and 30 Polish companies, matched in terms of employee count and age. Data was gathered between 2022 and 2023.

2. LITERATURE REVIEW

2.1. Resilience in family firms – what we know and what we don’t

The word “resilience” was used in the field of ecology. It was Holling in 1973 who first emphasized it, defining it as the ability to glean lessons from changes in the external environment and adapt to them to survive. In the physical and engineering realm, resilience describes a system’s capacity to absorb disruptions and disturbances that perturb its surrounding environment and, subsequently, return to a state of equilibrium (Patriarca et al., 2018). Another domain where this concept is employed is psychology; in this case, resilience is the ability of an individual to react to traumas and unpleasant events that affect them, resisting and eventually finding a new state of serenity (Schwarz, 2018). The concept of resilience is also employed in the field of economics. In this case, it is referred to as organizational resilience. Resilient companies are better equipped to handle external shocks than their fragile or robust counterparts and can learn and grow from these experiences. The underlying concept in all the definitions provided, for each context in which the analysed term finds its place, remains the same: resilience represents the ability of a system, as well as an individual, to react to external changes with determination to find a new point of equilibrium.

Family firms' ability to address adversity has been a subject of interest, and organizational resilience is associated with a set of interconnected mechanisms. While various studies have outlined mechanisms contributing to organizational resilience, a commonality emerges concerning the dynamic capability perspective (Salvato et al., 2020).

Although the family's strategic role has been recognized for decades, applying the dynamic capability lens to research on organizational resilience in family businesses remains underexplored. Organizational resilience, viewed as a dynamic capability, is activated when a firm encounters unexpected environmental events and internal strains that could jeopardize survival. This perspective focuses on the ability to perform specific activities reliably and satisfactorily (Yu et al., 2019).

Understanding organizational resilience as an ambidextrous dynamic capability is fundamental to the definition. It shapes the competitive advantage of a family firm in significant ways, yet the complex relationship between resilience and competitive advantage is not a primary focus of organizational scholars. Some studies have explored how dynamic capabilities help balance exploration and exploitation, with the dynamic capabilities theory suggesting that they provide a relatively persistent source of competitive advantage for firms (Pratono, 2022).

In conclusion, resilience is fundamental concept that applies to wide range of contexts, from ecology to economics, from psychology to organizational management. It reflects the ability to adapt and thrive in the face of external changes and adversities, taking on multiple facets depending on the field of study. Within the realm of family businesses, organizational resilience emerges as a dynamic capability that can confer a significant competitive advantage, although it remains a relatively unexplored research area. Understanding and developing organizational resilience thus becomes a key challenge for family businesses aiming to thrive in an unpredictable and ever-evolving environment.

In organizational settings organizational resilience stems from different sources. In the paper we focus on comparing five of them – namely, past firm performance, organizational unlearning, perceived as an ability to forget ineffective routines, processes, and procedures, firm innovation, slack resources available, and environmental dynamism. All of these factors are proven to be linked to increased organizational resilience (see: Conz et al., 2023; Do et al., 2022; Orth & Schuldis, 2021; Santoro, Messeni-Petruzzelli & Del Giudice, 2021). However, little is known on their influence on organizational resilience of family businesses. And even less is known how diverse cultural differences affect the influence of these factors on family firm resilience in different countries. In the following part the specificity of entrepreneurship in Italy and Poland is presented.

2.2. Family businesses in Italy and Poland – a descriptive comparison attempt

The resilience of family businesses, a pivotal aspect of their sustained success, is significantly influenced by the distinctive characteristics embedded in the economic and cultural contexts of specific regions. This study undertakes a comparative analysis of the characteristics shaping the resilience of family businesses in Italy and Poland, shedding light on the nuanced dynamics at play.

Italian family businesses exhibit a profound attachment to traditional values, notably emphasizing trust, loyalty, and generational continuity. This cultural orientation fosters a cohesive internal environment and cultivates an organizational culture grounded in a sense of belonging and long-term stability. The structural flexibility inherent in these businesses enables rapid adaptation to evolving market conditions, thereby providing a competitive advantage. Moreover, a relentless commitment to excellence and continuous improvement stands as a hallmark, resulting in the delivery of high-quality products and services across diverse sectors, including fashion, design, automotive, and food.

Conversely, family businesses in Poland showcase characteristics aligned with the economic and cultural landscape of the country. Notably, organizational flexibility emerges as a defining feature, empowering businesses to respond promptly to dynamic market changes.

Many Polish family enterprises exhibit a pronounced proclivity for innovation, consistently seeking to introduce novel products and services to the market. This adaptability to a continually shifting business environment reflects the imperative to address both challenges and opportunities effectively. The management structures within these businesses often display a degree of flexibility, facilitating agile decision-making processes.

In both Italy and Poland, the resilience of family businesses is grounded in their unique strengths. Family cohesion, efficient internal resource utilization, and effective decision-making collectively contribute to their ability to navigate challenges successfully. This resilience is not only instrumental for overcoming adversities but also for capitalizing on emerging opportunities within the dynamic business landscape.

Understanding the distinct characteristics influencing family businesses in Italy and Poland provides invaluable insights into the factors underpinning their resilience. This comparative analysis may serve as a foundation for developing strategic approaches to enhance the adaptive capacity and ensure the long-term success of family enterprises within these unique business environments.

3. METHODOLOGY

3.1. Research approach

Case-based methodologies, such as fsQCA and cluster analysis, have been utilized as a means of transcending variance-centric approaches (Cooper & Glaesser, 2011). These two methodologies share similarities, employing multidimensional spaces. Frequently, inquiries arise about the distinctions between fsQCA and cluster analysis and the rationale for their necessity. A primary disparity lies in research questions they can effectively address (Greckhamer et al., 2018). Specifically, cluster analysis addresses queries about the similarity between cases, whereas fsQCA can pinpoint various configurations constituting sufficient and/or necessary conditions for the desired outcome (Greckhamer et al., 2018; Ordanini et al., 2014). The choice of the most suitable methodology depends on the study's focal point. Distinctions arise from the fact that "QCA handles the positioning of cases in [multidimensional] spaces via set theoretic operations, while cluster analysis relies on geometric distance measures and concepts of variance minimization" (Cooper & Glaesser, 2011). Previous research endeavors have compared fsQCA with cluster analysis, demonstrating how fsQCA adeptly manages causal intricacies with granular data (Fiss, 2011), or how it can identify a greater number of solutions compared to cluster analysis (Ordanini et al., 2014). The literature engages in a discourse on QCA and cluster analysis (Greckhamer et al., 2018; Miller, 2018), each approach boasting unique distinctions that render them suitable for diverse study types.

This paper delves into an examination of the dynamics among organizational unlearning, firm innovation, firm performance, environmental dynamism, and organizational slack resources. The overarching objective is to scrutinize the interplay of these elements and their impact on organizational resilience within specific economic contexts, discerning configurations that either enhance or impede resilience. To discern resilience disparities between Italian and Polish enterprises, a comprehensive mixed-method approach is employed, with a specific emphasis on fuzzy-set qualitative comparative analysis (FSQCA), drawing inspiration from the methodological framework articulated by Pappas and Woodside (2021). This analytical approach facilitates an exploration of complex causal patterns, permitting an examination of both necessity and sufficiency conditions and offering insights into the diverse pathways leading to organizational resilience.

FSQCA stands as a systematic analytical framework designed to unveil causal relationships by analyzing combinations of conditions leading to specific outcomes. Its utility extends to the exploration of both necessity and sufficiency conditions, thereby affording insights into the multifaceted pathways to organizational resilience across diverse economic landscapes. Subsequent sections of this paper will delve deeper into the specificity of the FSQCA methodology and its application in the research.

3.2. Sample characteristics

To illuminate the mechanisms underpinning organizational resilience in Italian and Polish contexts, a cohort comprising 30 entrepreneurs from each country, representing micro, small, and medium enterprises, is engaged in the study. Commencing with a survey administered to Polish entrepreneurs in early 2023, data collection from Italian counterparts spans from October 2023 to January 2024.

In soliciting participation from Italian enterprises, determined efforts are exerted to ensure comparability in terms of company size, notwithstanding challenges encountered in aligning industry types across the sample due to logistical constraints.

The average age of Italian companies (12,46 years) surpasses that of Polish counterparts (5,36), a distinction accentuated by a notably wider standard deviation (11,9 years vs 6,66 years). Conversely, in terms of size, quantified by the number of full-time equivalent (FTE) employees, both Italian (17,56 FTE) and Polish (17,66 FTE) enterprises exhibit comparable means, accompanied by similar standard deviations (14,72 vs 14.49).

In the sample there were companies from different industries – production, service, and trade. In Italian sample there were 11 production, 12 service, and 7 trade companies. In the Polish sample there were 10 production, 16 service, and 4 trade companies. As for the scope of operation of studied companies, there were 7 local, 10 regional, 8 national, 4 international and 1 global company. With regards to the Polish sample, there were 14 local, 7 regional, 7 national, and 2 global companies. As depicted above, the analyzed data from enterprises is sharing commonalities, including familial ownership structure and sectoral alignment. However, a discernible divergence emerges regarding the scale of operations, with Italian companies in the sample exhibiting a greater degree of internationalization compared to their Polish counterparts.

3.3. Measures

The main dependent variable under investigation in this study is organizational resilience, measured through a tool previously validated by Orth and Schuldis (2021). This instrument comprises eight items evaluated on a 7-point Likert scale, demonstrating commendable internal consistency with a Cronbach's alpha coefficient of 0.884, surpassing the conventional threshold of 0.7. Exploratory factor analysis, employing principal component analysis with Varimax rotation, revealed a unidimensional construct elucidating slightly over 56% of cumulative variance. This conclusion is substantiated by robust statistical indices, including a Kaiser-Meyer-Olkin Measure of Sampling Adequacy of 0.878 and a Bartlett's Test of Sphericity yielding $p<0.001$.

Organizational unlearning, identified as another pivotal variable, was assessed utilizing a scale proposed by Lyu et al. (2020), consisting of six items with a Cronbach's alpha coefficient mirroring the high internal consistency observed for organizational resilience. Similarly, factor analysis unveiled a unidimensional construct capturing 63.6% of cumulative variance, further substantiated by statistical metrics (Kaiser-Meyer-Olkin Measure of Sampling Adequacy = 0.857; Bartlett's Test of Sphericity $p<0.001$).

Subjective evaluation of organizational performance, in accordance with the methodology advocated by Schilke (2014), was operationalized through a 6-item scale, boasting an impressive Cronbach's alpha coefficient of 0.920. This construct, too, exhibited unidimensionality, with one factor elucidating 71.7% of cumulative variance, bolstered by robust statistical indices (Kaiser-Meyer-Olkin Measure of Sampling Adequacy = 0.889; Bartlett's Test of Sphericity $p<0.001$).

Innovation, a pivotal facet of organizational dynamics, was quantified by the number of novel products and/or services introduced within the preceding three years, adhering to guidelines outlined in the Oslo Manuals.

Environmental dynamism, recognized as a contextual variable of significance, was assessed utilizing a scale proposed by Sutcliffe (1994), encompassing seven items with a Cronbach's alpha coefficient of 0.819. Consistent with previous constructs, this measure exhibited unidimensionality, with one factor explaining 68.8% of cumulative variance.

Slack resources, deemed crucial for organizational adaptability, were gauged through a succinct scale of two items, as suggested by Khan and Mir (2019), demonstrating internal reliability with a Cronbach's alpha coefficient of 0.739.

Subsequently, metavariables were computed as means of items within their respective constructs, followed by an in-depth analysis of descriptives and correlations, elucidating the intricate relationships among the variables. Detailed results are meticulously presented in Tables 1 and 2 for a comprehensive understanding and interpretation.

Table 1. Descriptives

Variable	Statistic	Italy	Poland	Two samples
Resilience	Mean	5.84	5.00	5.42
	Std. Dev.	0.90	0.70	0.90
Unlearning	Mean	5.52	4.64	5.08
	Std. Dev.	0.91	0.99	1.04
Performance	Mean	4.91	4.37	4.64
	Std. Dev.	0.97	0.98	1.00
Innovation	Mean	6.66	6.33	6.5
	Std. Dev.	5.13	8.65	7.05
Dynamism	Mean	5.33	4.54	4.94
	Std. Dev.	0.76	0.85	0.89
Slack resource	Mean	5.23	4	4.61
	Std. Dev.	1.40	1.14	1.41

Table 2. Correlations between variables (in the whole sample)

Correlations						
	1	2	3	4	5	6
1. Resilience	1					
2. Organizational unlearning	.680**	1				
3. Organizational performance	.532**	.505**	1			
4. Innovation	.326*	.196	.342**	1		
5. Environmental dynamism	.694**	.572**	.689**	.322*	1	
6. Slack resources	.547**	.462**	.639**	.275*	.758**	1
**. Correlation is significant at the 0.01 level (2-tailed).						
*. Correlation is significant at the 0.05 level (2-tailed); N=60.						

On average, survey participants from Italian enterprises manifested heightened levels of organizational resilience, a more pronounced inclination towards the disengagement of ineffective practices, superior performance metrics, and a more substantial availability of slack resources in comparison to their counterparts from Polish companies. Intriguingly, Italian respondents also demonstrated a perception of their operational environment as being more dynamic. Nevertheless, somewhat unexpectedly, they reported a lower incidence of introducing new or modified products or services compared to their Polish counterparts.

As evident from the correlation table, a majority of the variables exhibit significant correlations. Notably, organizational resilience demonstrates robust associations with unlearning, perceived organizational dynamism, prior performance, and slack resources, while also displaying a moderate relationship with organizational innovation. The remaining correlations are predominantly positive and statistically significant, underscoring the interconnectedness of these constructs. While the correlation with innovation is comparatively weaker, it remains statistically significant.

3.4. Data preparation for fsQCA

FSQCA is particularly well-suited for investigations focused on exploring configurations of interconnected structures rather than isolating entities, as observed in disciplines such as consumer psychology (Schmitt et al., 2017). An intrinsic advantage of fsQCA lies in its capacity to accommodate naturally complex and non-linear relationships among variables, in contrast to variance-based approaches. The methodology identifies combinations of conditions sufficient for the occurrence of a specific outcome, utilizing both qualitative and quantitative assessments to ascertain the extent to which a given case belongs to a defined set. Given that fsQCA facilitates the exploration of solutions elucidating the outcome of interest (Pappas et al., 2016), this methodological approach was adopted to discern the preconditions influencing the organizational resilience of Italian and Polish companies.

The empirical process for implementing fsQCA involves the calibration of the dataset, transforming data into fuzzy sets with values ranging from 0 to 1. Calibration measures assume a critical role in evaluating the goodness of model fit. Through the calibration procedure, the researcher could integrate data from various Likert scales, showcasing another advantageous aspect of fsQCA (Pappas & Woodside, 2021).

Initially, the dataset underwent division into two distinct sub-sets, segregating data pertaining to Italy and Poland, respectively. Subsequently, in the ensuing step, the calibration of the dataset into fuzzy sets was executed. Statistical parameters utilized for calibration are presented in Table 3, separately for Italy and Poland. Consistent with the recommendations of Pappas and Woodside, percentiles of 95th, 50th, and 5th were employed during the calibration process.

The analysis yielded three combinations of configurations: complex, parsimonious, and intermediate. However, only the combinations of parsimonious and intermediate configurations were employed to formulate conclusions, systematically presented in a specific tabular format as fsQCA findings.

Table 3. Statistics for the calibration of the datasets

ITALY						
Statistics:	Unlearning	Innovation	Resilience	Dynamism	Slack resources	Performance
95th percentile	7,000	18,150	7,000	6,493	7,000	6,500
median	5,333	5,500	5,938	5,429	5,500	5,167
5th percentile	3,958	1,000	3,763	3,643	1,825	3,258
POLAND						
95th percentile	6,542	33,100	6,375	6,000	5,725	6,408
median	4,583	4,000	4,875	4,429	4,000	4,167
5th percentile	2,717	0,000	4,194	3,143	1,500	2,717

4. RESEARCH RESULTS

The main research was conducted using the truth table analyses for discerning high and low levels of organizational resilience in Italy, as well as for high and low organizational resilience in Poland. The frequency cutoff was set to 0, thereby encompassing the entirety of the 30 cases in the analyses. Various consistency cutoffs were instituted at distinct levels, as detailed in tables containing the results, while configurations exhibited variability. After the estimation process, we derived the parsimonious and intermediate combinations of configurations, which are documented in Tables 4, 5, 6, and 7.

Table 4. Pathways to **high** organizational resilience in **Italian companies**

Intermediate solution			
Frequency cutoff	1		
Consistency cutoff	0.914077		
	raw coverage	unique coverage	consistency
UNLEARN*DYNAM	0.748795	0.0951807	0.918699
UNLEARN*SLACKRES*PERF	0.598795	0.0253012	0.940397
DYNAM***SLACKRES***PERF	0.63253	0.0283132	0.925926
~UNLEARN*~INNOVAT***SLACKRES***~PERF	0.301807	0.0240964	0.909256
UNLEARN*INNOVAT*~SLACKRES*~PERF	0.324699	0.0234939	0.919795
solution coverage: 0.880723			
solution consistency: 0.869203			

Legend: Unlearn – organizational unlearning; dynam – environmental dynamism, slackres – slack resources, perf – organizational performance, innovat – innovation.
"~" means low level of a condition; lack of "~" means high level of a condition for an outcome to occur.

Table 5. Pathways to **low** organizational resilience in **Italian companies**

Intermediate solution			
Frequency cutoff	1		
Consistency cutoff	0.84513		
	raw coverage	unique coverage	consistency
~UNLEARN*~DYNAM*~SLACKRES***~PERF**	0.675373	0.356716	0.934917
~UNLEARN*~INNOVAT*SLACKRES***~PERF**	0.371642	0.0462685	0.903811
UNLEARN***~INNOVAT*~DYNAM***SLACKRES*PERF	0.285075	0.0567163	0.845133
solution coverage: 0.785074			
solution consistency: 0.887015			

Legend: Unlearn – organizational unlearning; dynam – environmental dynamism, slackres – slack resources, perf – organizational performance, innovat – innovation.
"~" means low level of a condition; lack of "~" means high level of a condition for an outcome to occur.

Table 6. Pathways to **high** organizational resilience in **Polish companies**

Intermediate solution			
Frequency cutoff	1		
Consistency cutoff	0.84513		
	raw coverage	unique coverage	consistency
UNLEARN***DYNAM***SLACKRES	0.597222	0.0884504	0.777355
INNOVAT***DYNAM***SLACKRES	0.548246	0.00730991	0.791139
INNOVAT***DYNAM***PERF	0.555556	0.0153509	0.805085
~UNLEARN***DYNAM***~SLACKRES*PERF	0.372076	0.0131578	0.800314
UNLEARN*INNOVAT*~DYNAM*~SLACKRES*~PERF	0.284357	0.0372807	0.762745
UNLEARN*~INNOVAT*~DYNAM*~SLACKRES***PERF**	0.311403	0.0438596	0.760714
solution coverage: 0.820906			
solution consistency: 0.754198			

Legend: Unlearn – organizational unlearning; dynam – environmental dynamism, slackres – slack resources, perf – organizational performance, innovat – innovation.
~ means low level of a condition; lack of "~" means high level of a condition for an outcome to occur.

Table 7. Pathways to **low** organizational resilience in **Polish companies**

Intermediate solution			
Frequency cutoff	1		
Consistency cutoff	0.84513		
	raw coverage	unique coverage	consistency
UNLEARN*~INNOVAT*~DYNAM*~PERF	0.400735	0.0643382	0.875502
~UNLEARN*~INNOVAT***~DYNAM*SLACKRES**	0.435662	0.0453431	0.967347
~UNLEARN*~INNOVAT*~DYNAM***PERF**	0.409926	0.0294117	0.901617
~UNLEARN*DYNAM***~SLACKRES*PERF**	0.355392	0.03125	0.91195
~UNLEARN*INNOVAT*~DYNAM***~SLACKRES*~PERF**	0.287377	0.00612748	0.926877
~UNLEARN*INNOVAT*DYNAM***SLACKRES*~PERF**	0.322917	0.00551468	0.899317
solution coverage: 0.648897			
solution consistency: 0.856796			

Legend: Unlearn – organizational unlearning; dynam – environmental dynamism, slackres – slack resources, perf – organizational performance, innovat – innovation.
~ means low level of a condition; lack of "~" means high level of a condition for an outcome to occur.

In the initial phase, it is imperative to underscore that, across all identified solutions, both coverage levels and consistency exhibit a relatively high degree, surpassing the cut-offs stipulated by Pappas and Woodside (2021). This substantiates the assertion that these configurations aptly represent the data, providing a reliable explanation of the outcomes.

5. DISCUSSION

The outcomes delineate distinctive configurations of factors influencing organizational resilience in Italian and Polish companies. Despite similarities in sample characteristics, such as size, industry, and age, noteworthy divergences in outcomes are apparent. In Italian companies, elevated organizational resilience predominantly hinges on the capacity to unlearn outdated processes and the presence of abundant slack resources. Factors like organizational performance, innovativeness, and environmental dynamism assume comparatively less significant roles in fostering heightened resilience. Conversely, diminished resilience in Italy is associated with low levels of innovativeness, environmental dynamism, unlearning, and past

performance. This may be attributed to the substantial accumulation of organizational slack in preceding years, fostering a sense of complacency regarding crisis preparedness.

In contrast, attaining heightened organizational resilience in Polish companies proves to be a significantly more intricate undertaking. A combination of factors, including adaptability to a dynamic environment, effective unlearning, innovation, and a track record of past performance, emerges as essential. Multiple pathways leading to enhanced organizational resilience in Polish companies exist. Conversely, reduced resilience often stems from a combination of limited unlearning capabilities and operation within a relatively stable environment. However, diverse configurations of these factors can still culminate in diminished organizational resilience in Polish contexts. For instance, irrespective of an organization's innovativeness, availability of slack resources, or past performance, unfavorable configurations of other factors may impede resilience.

The findings suggest that the pathways to reduced organizational resilience in Polish companies are diverse. This could be partly attributed to the relatively younger average age of the studied Polish companies compared to their Italian counterparts, limiting their exposure to crisis management experiences. Further research on this topic is imperative to garner deeper insights into the nuanced dynamics influencing organizational resilience in diverse contexts.

In conclusion, the in-depth examination of resilience in family businesses in Italy and Poland has yielded a more nuanced understanding of this phenomenon, considering the distinctive cultural and economic nuances of each nation. In Italy, the family orientation extends beyond being a mere organizational characteristic, emerging as a genuine cohesive nucleus that contributes to establishing a corporate culture grounded in fundamental principles of trust, loyalty, and generational continuity. These values have proven decisive in ensuring long-term stability and effective management of Italian family businesses.

Conversely, in Poland, organizational flexibility and an innovative approach stand out as primary drivers of resilience. The readiness to adapt to changing market conditions and openness to innovation have enabled Polish family businesses to thrive in a dynamic economic environment.

Both contexts share a deep connection to traditions, indicating that despite cultural differences, the preservation of family values is a central element in the resilience of family businesses. However, it is crucial to emphasize that the adopted strategies may vary, highlighting that resilience takes on differentiated manifestations based on cultural and economic contexts.

In both Italy and Poland, the robustness of family enterprises finds its foundation in their distinctive competencies. The unity within the family, adept utilization of internal resources, and judicious decision-making collectively contribute to their adept navigation of challenges. This resilience not only proves pivotal in overcoming adversities but also in capitalizing on emergent opportunities within the dynamic business milieu.

Comprehending the unique attributes shaping family enterprises in Italy and Poland yields invaluable insights into the factors buttressing their resilience. This comparative scrutiny establishes a groundwork for formulating strategic approaches aimed at augmenting their adaptive capabilities, thereby ensuring the enduring success of family enterprises within these distinctive business ecosystems.

Considering the ongoing global challenges, understanding these intricate dynamics becomes imperative to devise targeted approaches to support and further strengthen the crucial role of family businesses in their respective national contexts.

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Original research

GOLD PRICE PREDICTION BASED ON THE MONTE CARLO METHOD

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Abstract: Gold is a precious metal that attracts the attention of authors from various fields. Due to its wide application in various industries, it is a very important resource for the business of many companies. In this paper, the price of gold was predicted for a period of one year, based on historical data, for approximately five years. Price forecasting was performed based on the Monte Carlo method, and the simulation itself was performed in the MATLAB software. The aim of this paper is to help the management of companies for which gold is a significant resource in planning and making business and financial decisions. The result of the forecast allows the management to create different scenarios to be ready to react to almost any situation on the market, and thus to maintain the position of the company they lead.

Keywords: Monte Carlo method, Price prediction, Gold market, MATLAB.

1. INTRODUCTION

Gold is a precious metal because of its specific physical and chemical characteristics. This metal has been highly valued throughout the world for centuries. Due to its wide and specific use, it is considered a highly sought after commodity. Global demand for gold is met from two sources. The first, the dominant one, involves the mining of gold, while the second refers to the supply of gold from recycled sources to the world market. The largest producers of gold in the world are China (375t), Russia (324.7t) and Australia (313.9t) (World Gold Council, 2024). These countries produce about 1,000t of gold per year. Gold production for the period 2010-2023 is given in Figure 1 (World Gold Council, 2024).

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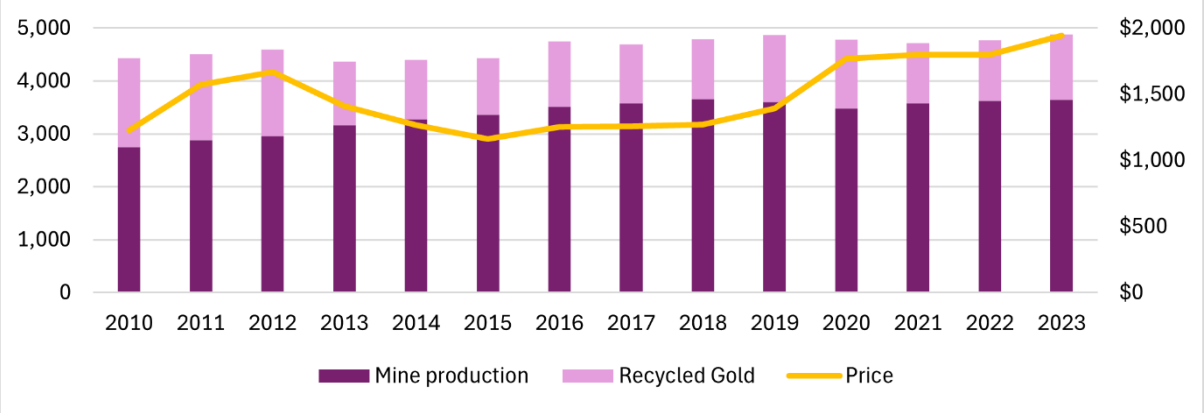

Figure 1. Gold production sources and average market price for period 2010-2023 (Adjusted according to World Gold Council, 2024)

Figure 1 shows that gold production for the observed period has a slight increase. Figure 1 also shows the movement of the average price of gold per unit Oz, for the observed period. As can be seen, the price fluctuates during the observed period, but since 2020 there has been an increase in the price of gold, expressed in USD per Oz unit.

Gold has a very wide range of uses. According to data available on the World website Gold Council Gold's miscellaneous uses, in jewelry, technology and by Central banks and investors, mean different sectors of the gold market rises to prominence at different times points in the global economy cycles. The use of gold in the world market for the period 2010-2023 is given in Figure 2.

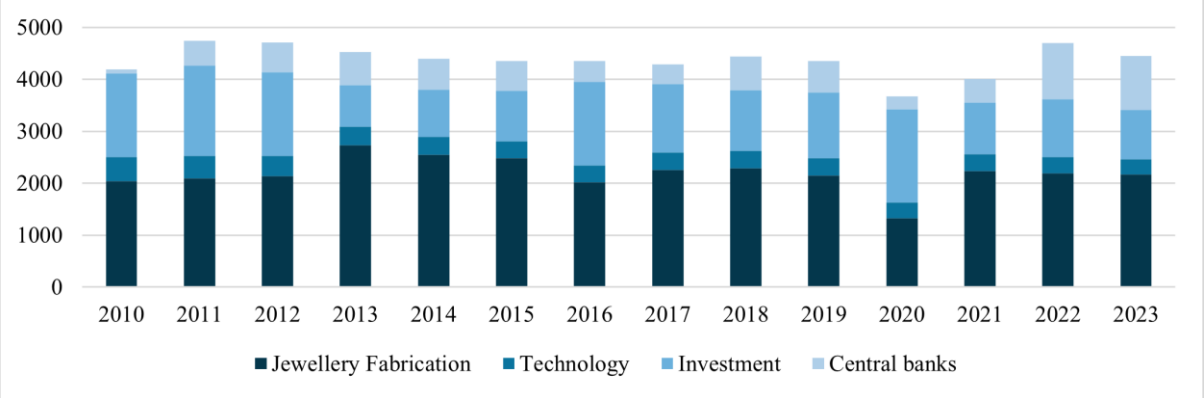

Figure 2. The use of gold in the world market for the period 2010-2023 (Adjusted according to World Gold Council, 2024)

In Figure 2, it can be seen that during the observed period, the use of gold was mostly directed towards the production of jewelry. In addition, gold is used for investment, in the production of technological components, as well as in banks in the form of reserves.

Based on the above, gold is a very important resource in the business of companies around the world, which operate in the mentioned areas (Figure 2), but gold is not only used in these areas. Due to its wide application, monitoring the movement of the price of gold is extremely important, so that the management of the companies that use it can make timely and correct business decisions. The goal of this paper is to forecast future price movements based on gold prices on the stock exchange from the previous time period, based on which the management of the company can make business decisions or plan future activities. After a short introduction, the paper will present the use of the Monte Carlo methodology in stock price

forecasting, after which the methodological approach to price forecasting and initial data will be presented. Finally, the paper will present the obtained results and concluding considerations, i.e. guidelines that could be helpful to managers in business and financial planning.

2. LITERATURE REVIEW

Gold price volatilities have a significant impact on many financial activities of the world. Gold, as a very well-known precious metal, is very attractive for a lot of authors in different spheres of researching, and the gold price prediction is a subject that leads. Accurate forecasting of prices is a very challenging task due to the volatile and nonlinear nature of the financial stock markets (Jevtić et al., 2023). Researchers and academicians are still working on the best way in finance and economics to conquer this challenge (Makala & Li, 2021)

In the literature, there are authors that focus their research on the stock price prediction (Shafiee & Topal, 2010; Jevtić et al., 2023; Čečević et al., 2023). Some authors in their research provided a review of available methods for gold price prediction (Zainal & Mustafa, 2015). Some authors (Brabenec et al., 2020; Salis et al., 2019) used combination of various methods in their stock price predictions research. Sami and Junejo (2017) in their research used techniques based on the machine learning, while Manjula and Karthikeyan (2019) did a combination of machine learning and regression analysis. Some authors did the prediction using the deep learning techniques (He et al., 2019; Vidya & Hari, 2020; Dhanush et al., 2021). Some authors used ARIMA model for stock price prediction (Makala & Li, 2021; Yang, 2019; Tripathy, 2017), while the others used a combination of ARIMA model and neural networks (Adebiyi et al., 2014).

Many of them focused on the gold price predictions using one specific method. Madziwa et al. (2022) in their research did gold price prediction based on the multivariate stochastic model. Xiang et al. (2021) for the gold price prediction used Monte Carlo method. Some authors in their research, beside gold price prediction based on Monte Carlo method, analysed gold price returns (Chai et al., 2021). Many of them combined Monte Carlo method with other available methods for not only predicting gold price but the risks, too (Baur et al., 2016).

Monte Carlo method is widely used for stock price prediction in various industries and used by some groups of authors (Brodd & Djerf, 2018; Xiang et al., 2021; Jevtić et al., 2023; Čečević et al., 2023).

Based on the review of the literature, there are different groups of authors who base their research on predicting the price of gold using different methodologies or their combination. Nevertheless, the literature review indicates that price prediction can also be performed using the Monte Carlo method, which has not been widely applied to the given topic. Therefore, the contribution of this paper is that it provides a new perspective of price forecasting that can be used as a basis for making important business and financial decisions. In the following, this methodology will be explained, and the results of the conducted simulation will be presented.

3. METHODOLOGY AND DATA

The Monte Carlo method is a numerical method for solving the most complex requirements. Stanislaw Marcin Ulam, Enrico Fermi, John von Neumann, and Nicholas Metropolis are considered the first authors who gave importance to this method and its application. Ulam applied this method to games of chance. After extensive research, he managed to develop the pattern into a two-dimensional game based on very simple rules. His

work was the basis for the development of far more complex methods in engineering. The potential of this method was soon recognized by John von Neumann, who wrote a program for the first computer, ENIAC, which was used to solve the problem of neutron diffusion using the Monte Carlo method (Jevtić et al., 2013).

Hertz (1964) is one of the authors who analysed the potential of using the Monte Carlo Method (MCM) in the field of economics. Monte Carlo simulation is a method of analysis based on artificially recreating a random process (usually using a computer), running it multiple times, and directly observing the results (Barreto & Howland, 2006). Very simple as well as very complex problems can be solved by simulation. Some problems can be solved manually. However, most require the use of software, such as Excel, R Studio, MATLAB, and similar. Without these programs, solving certain problems would take a very long time (Jevtić et al., 2023).

In this paper, gold price prediction (forecasting) is done for a period of one year (the average number of trading days on the stock exchange is 252, so that value is considered representative) using the MATLAB software. Prediction is done based on the historical data for adjusted closing market prices for period of approximately 5 years (approximately 1350 working days) or more specific for period since 1st of January 2019 to 30th of April 2024. Data are downloaded from Yahoo finance (2024) that provide stock price information. For Gold, data are redistributed from the stock market COMEX LME. Prediction is set for 1,000 outcomes.

To use the Monte Carlo method for the price prediction, the historical data have to be stochastic. Thus, the first step in the simulation is to determine the type of data that is included. Figure 3 presents the historical data for the observed period.

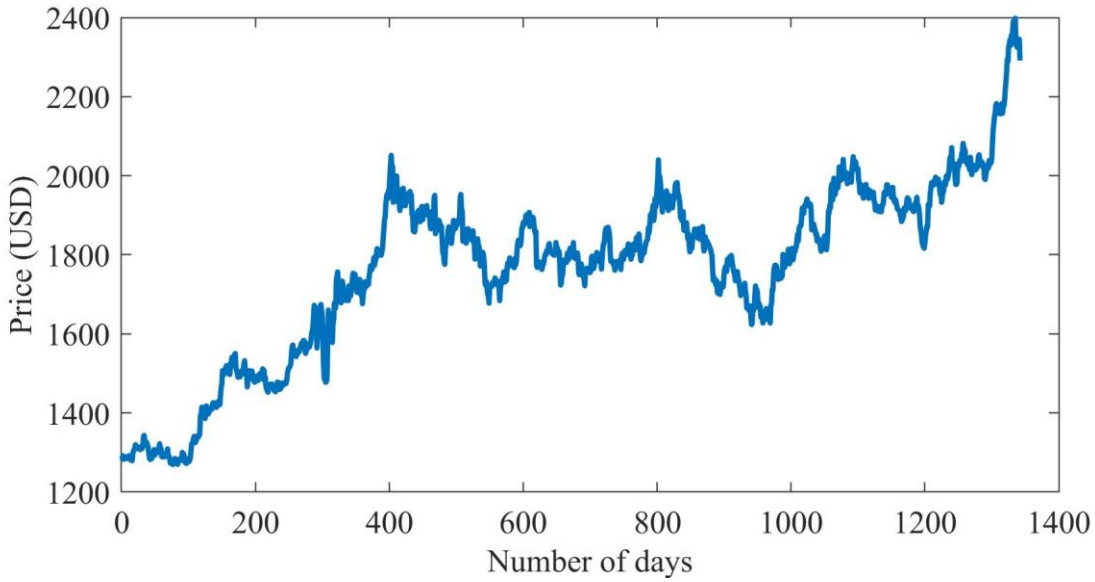

Figure 3. Gold prices for period 1st of January 2019 to 30th of April 2024 in USD per Oz (Adjusted according to Yahoo finance, 2024)

Figure 3 represents that the gold's price movement for the analysed period has a stochastic character, as there can't be described function that explains this change. Therefore, this data is suitable for running the Monte Carlo price prediction. For the analysed period, some statistical data is presented in Table 1.

Table 1. Descriptive statistics for analysed data (Adjusted according to Yahoo finance, 2024)

Data type for observed period	Maximum price	Minimum price	Average price
Data value (USD/Oz)	2,398.4	1,269.3	1,765.8

Based on the data shown in Table 1 it can be observed that for the observed period price has significant changes as the minimum price was 1,269.2 USD/Oz, while the maximum was 2,398.4 USD/Oz, and the average price for the analysed period is 1,765.8 USD/Oz.

Based on the corresponding code written for usage in software MATLAB, the normalized daily increase in the price is first computed, as well as the mean value and standard deviation for these data. Since this method of prediction is based on probability, the next step is the generation of random numbers. To generate random numbers, a function that recognizes the normal distribution of the numbers is used. Those random numbers represent simulated price increases for the future period based on which the price forecast for the future period is made (Jevtić et al., 2023).

4. RESULTS AND DISCUSSION

Price forecasting in this paper is done using the code for MATLAB. Prediction is based on the historical prices (adjusted closing prices) for the period from 1st of January 2019 to 30th of April 2024. Prediction is done for one year in future which is approximately 252 working days. The case of wanted scenarios is set to 1,000. The results of price prediction for the observed period is presented in Figure 4.

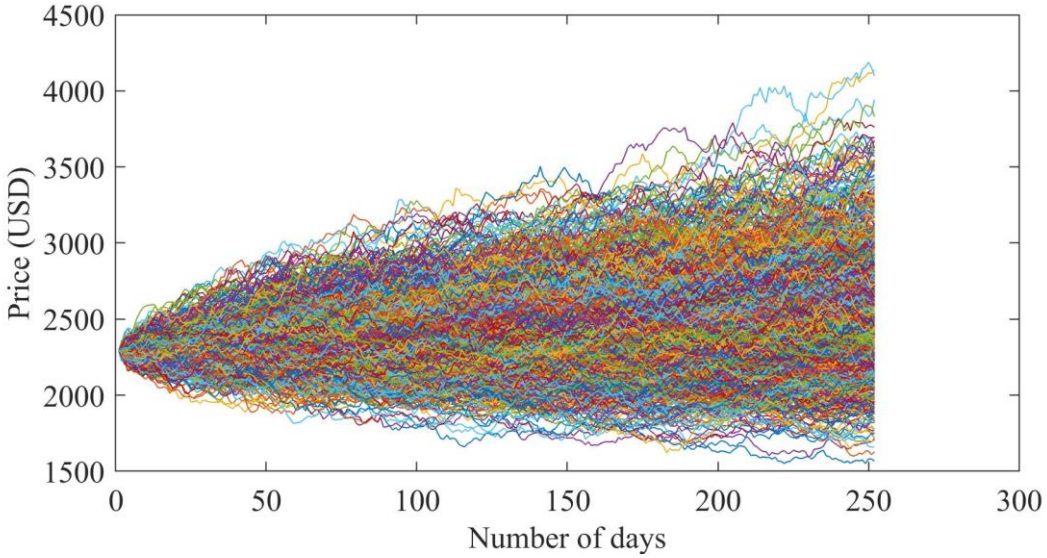

Figure 4. Gold price prediction results for predicted period of 252 days and 1,000 outcomes

On the Figure 4 the x-axis presents the number of days for which price is predicted, and on the y-axis presents the predicted price in USD/Oz. Regarding that the historical data is already determined as stochastic and with significant volatility, the prediction results vary, too. The comparation of historical data and predicted values is an additional analysis, based on which can be noticeable the variety of different scenarios. The comparation is presented in Figure 5.

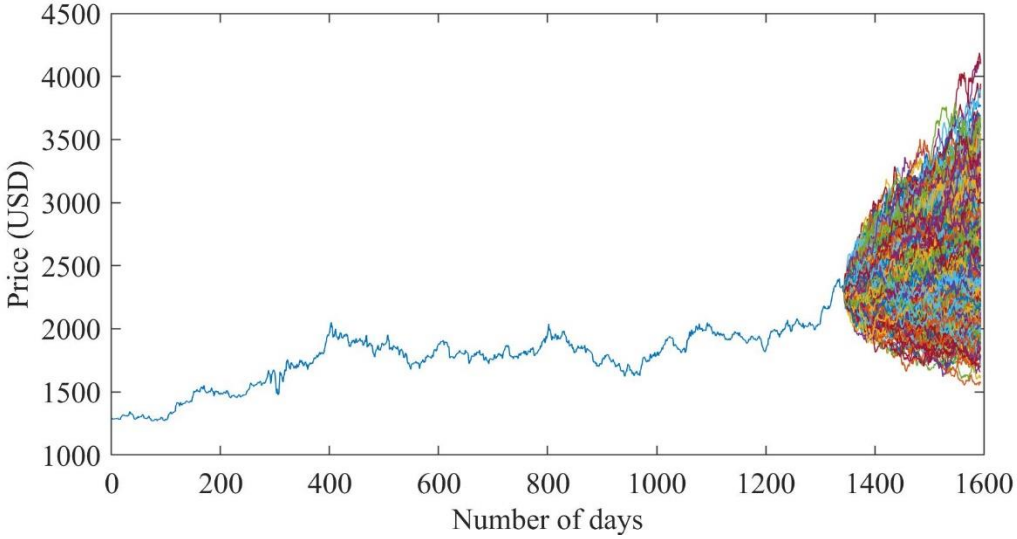

Figure 5. Summarized historical data and predicted prices for the observed period of 252 days and 1,000 outcomes

Simulation volatility for the whole period of 252 days is shown in Table 2.

Table 2. Simulated price volatility for the observed period and 1,000 outcomes

Data type for observed period	Maximum price	Minimum price	Average price
Data value (USD/Oz)	4,188.2	1,550.0	2,433.6

Based on data presented in Table 2 it can be noticed that taking into consideration all 1,000 outcomes price can vary between 1,550.0 USD/Oz which is minimum predicted prices to 4,188.2 USD/Oz which is maximum predicted price, but the most possible price will be close to 2,433.6 USD/Oz as this is the average price for the whole observed period.

Next part of the analysis is related to the distribution of simulated data. Figure 6 presents the data distribution for simulated values on 252nd day.

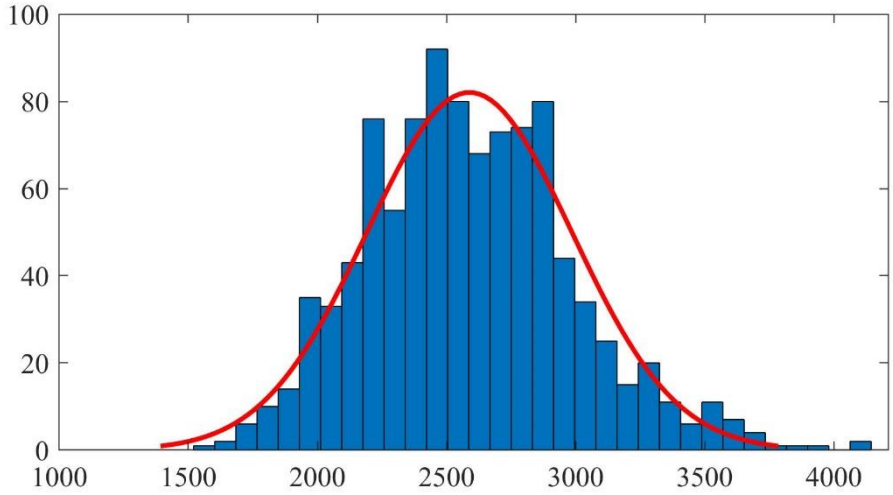

Figure 6. Distribution of simulated share prices on 252nd day.

Figure 6 presents the distribution of simulated prices on 252nd day. The values on the x-axis indicate the most common values of the prices of the simulated actions in USD/Oz, whereas the y-axis reflects the number of times each price is repeated. In addition, the figure illustrates the normal distribution of the resulting data.

The additional analysis regarding simulated values on 252nd day provide descriptive values of the results, which is presented in Table 3.

Table 3. Descriptive statistic values of price for 252nd day of prediction

Data type for observed period	Maximum price	Minimum price	Average price	Standard Deviation	Standard Error
Data value (USD/Oz)	4,136.7	1,566.5	2,588.3	398.6458	12.6063

Table 3 presents the descriptive statistic values of predicted gold's price. In 252 working days (one year) according to prediction the price will vary between 1,566.5 USD/Oz and 4,136.7 USD/Oz. The most probably price will be close to the average which is determined at 2,588.3 USD/Oz. Standard deviation of 398.6458 USD indicate to significant volatility of the price, while standard error indicates average price deviation per scenario which is approximately 12.6 USD.

5. CONCLUSION

In this paper, the gold price prediction was done using the Monte Carlo method, based on the code prepared for MATLAB. The analysis was conducted based on the historical data downloaded from Yahoo finance (2024) for the period from 1st of January 2019 to 30th of April 2024. The required number of outcomes was 1,000, and the prediction period was determined to be one year (252 working days).

As the historical (input) data had a significant level of volatility, the results also indicate a significant level of volatility. By comparing input data statistics (Table 1), data simulated for the whole period (Table 2), and data simulated on the 252nd day (Table 3) it can be concluded that the longer period of prediction is, the greater volatility can be expected.

Although forecasting can never provide the most accurate results, it is still a useful tool for company management as it provides some basic guidance on potential price movements. Based on the information about the minimum, maximum and average expected prices in the future, the management can create various business scenarios and, depending on the actual situation, react readily to whatever scenario befalls the company it manages.

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DYNAMIC EFFECT OF ENTREPRENEURIAL UNIVERSITY ENVIRONMENT ON STUDENT'S ENTREPRENEURIAL SELF-EFFICACY

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Abstract: This study investigates the relationship between the university environment and entrepreneurial self-efficacy among students across three survey periods: 2021, 2018, and 2016. The research considers an analysis based on major implications proposed by the GUESSS Project (Global University Entrepreneurial Spirit Students' Survey) to generate in-depth insights into students' entrepreneurial self-efficacy.

Utilizing a series of items measuring positive appraisal of the university environment and entrepreneurial self-efficacy, data was collected via a 7-point Likert scale from a sample of students. Reliability analysis using Cronbach's Alpha demonstrated excellent internal consistency for both constructs across all measured periods.

Pearson correlation analysis revealed significant positive correlations between positive appraisal of the university environment and entrepreneurial self-efficacy in 2021 and 2018, indicating that as students perceive a more supportive and encouraging entrepreneurial environment at their university, their confidence in entrepreneurial activities increases.

These findings underscore the importance of the university environment in development entrepreneurial self-efficacy among students, while also highlighting potential temporal variations in its impact. Understanding these dynamics can inform educational policies and practices aimed at fostering entrepreneurial skills and mindsets among students, thus contributing to the advancement of entrepreneurship education and the cultivation of future entrepreneurial leaders.

Keywords: entrepreneurship, university environment, entrepreneurial self-efficacy, entrepreneurial education, GUESSS

1. INTRODUCTION

The main goal of modern education systems is the development of competent students and future citizens, employees, experts and entrepreneurs, and the vision of a society based on

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knowledge is a vision of society where competent people whose ideas, innovations and knowledge are the main driver of development. Advanced society is based on enterprising people and entrepreneurial activity. It is present on a global level and it can be seen everywhere - both in developing countries and in countries that are industrial super-powers. The success of entrepreneurial education (EE) today connects the political, academic, scientific, and professional realms and permeates every social stratum in western society (Mitaseva, 2022).

The entrepreneurial university is emerging as a new archetype of higher education institution that fosters knowledge generation and transfer, contributes to local development, and empowers individuals in fast changing markets (Minola, et al., 2016). The university context might impact whether something gets initiated; hence it has been disputed that the university environment could be potentially considered as entrepreneurial ecosystem (Fetters et al., 2013). In this context, universities are considered as a much wider context than providing entrepreneurial education. In such a setting key component can include entrepreneurship course and degree offerings, engagement of alumni entrepreneurs, student incubators, prototype development services, seed funding to university start-ups, technology transfer services, and scholarly research, among others (Rideout & Gray, 2013).

In our research, we aim to extend this debate by examining some dimensions related to the entrepreneurial universities that are important to understand their specific characteristics as a very important determinant of future entrepreneurial activities of university students and their overall impact on the entrepreneurship processes. In this context we have examined the following underlying and fundamental, but very important dimension for further and deeper examinations of this subject such as the relationship between entrepreneurial university environment and entrepreneurial self-efficacy among students. The research considers an analysis based on major implications proposed by the GUESSS Project (Global University Entrepreneurial Spirit Students' Survey) to generate in-depth insights into students' entrepreneurial self-efficacy.

In order to provide more relevant and proven evidence on the effect of entrepreneurial education and to facilitate the development of strategies to strengthen entrepreneurial talent in higher education institutions, a correlation between three research periods was investigated to evaluate the effect of the university environment on students' entrepreneurial self-efficacy.

2. LITERATURE REVIEW

Entrepreneurship is a multifaceted phenomenon encapsulating the dynamic process by which individuals, known as entrepreneurs, identify, evaluate, and exploit opportunities in the marketplace through the creation, innovation, and management of ventures. It involves the application of creative thinking, risk-taking propensity, and resource mobilization to develop novel products, services, or business models that address unmet needs or redefine existing markets. Entrepreneurship and innovative individuals are the foundation of an advanced civilization. It exists on a worldwide scale and is evident everywhere, in both industrial superpowers and developing nations (Mitaseva, 2024).

According to Gubik (2021), in the year 1755, Richard Cantillon was the first person to use the term "entrepreneurship." Some people regard it as a process of successfully organizing a business, while others see it as the development of a certain attitude and set of abilities (Diandra & Azmy, 2020).

In everyday life it is considered the process of starting a business; in economics, some authors consider entrepreneurship to be classic management, others see the essence of entrepreneurship in systematic innovation and search for changes, and still others see a person who takes risks and invests (Drucker, 2006). Law regulation everywhere in the world describes

an entrepreneur as a natural person who starts his own business and manages it with him. Many definitions emphasize the propensity for change as the main characteristic of an entrepreneur, innovation, creativity and willingness to take risks - it is emphasized that the entrepreneur is looking for changes, responds to them and uses opportunities, while innovation is a tool of an entrepreneur because an effective entrepreneur turns opportunities into resources (Drucker, 1985). Under entrepreneurship it is also understood an individual's ability to turn ideas into action. This term implies creativity, innovation, initiative and risk taking, as well as the ability to plan projects and manage projects achievement of goals. Definitions of entrepreneur and entrepreneurship are numerous - there is no single and generally accepted definition, but each to a certain extent refers to knowledge and skills related to business, proactivity and innovation.

If the thesis is accepted that entrepreneurship is a process in which knowledge is transformed into practical results (Shane & Venkataraman, 2000), that entrepreneurship forms the basis development of intellectual capital (Zahra & Dess, 2001) and that an entrepreneur is not born but created (Drucker, 1993), then it is clear that the place of entrepreneurship is in the education system and the appropriate entrepreneurial education and entrepreneurial environment lead to the creation of successful entrepreneurs.

2.1. Entrepreneurial Education

Entrepreneurial education refers to a type of education that aims to cultivate entrepreneurial mindsets, skills, and behaviors in individuals. It goes beyond traditional academic learning by emphasizing creativity, innovation, risk-taking, and problem-solving in the context of entrepreneurship and business ventures.

While numerous studies (Fayolle et al., 2006; Bergmann et al., 2018; Fernández-Pérez et al., 2019; Mahdaly & Usman, 2020; Shah et al., 2020) have explored the impact of entrepreneurial education on individual human capital development and entrepreneurial aspirations, research suggests that student engagement in entrepreneurship courses extends beyond personal growth to encompass broader social ramifications. Furthermore, entrepreneurial education provides students with a foundational understanding of entrepreneurial concepts and fosters attitudes, behaviors, and mindsets conducive to entrepreneurship, thereby enhancing entrepreneurial self-efficacy (Boyd & Vozikis, 1994). Supporting this notion, Wardana et al. (2020) propose that structured curriculum models reinforcing entrepreneurial education correlate positively with entrepreneurial self-efficacy.

Entrepreneurship courses typically fall into two main categories: compulsory courses integrated into specific degree programs' curricula and elective courses where participation is optional (Krueger et al., 2000). Students have the autonomy to choose which courses to enroll in, reflecting varying levels of interest and motivation. Evaluating entrepreneurial self-efficacy (ESE) entails considering different dimensions, especially when the objective of a program is to accelerate startup rates. However, assessing changes in ESE, particularly in the startup context, offers insights into the effectiveness of the education or training provided. Close monitoring of post-program actions is crucial for gauging the practical impact on individuals (Barakat et al., 2014).

2.2. Entrepreneurial Self-Efficacy

It is generally acknowledged that entrepreneurial self-efficacy, which refers to an individual's belief in capability to perform tasks and roles aimed at entrepreneurial outcomes

(Chen et al., 1998), plays a crucial role in determining whether individuals pursue entrepreneurial careers and engage in entrepreneurial behavior.

The agency perspective, informed by self-efficacy research (Bandura, 1986), is seen as a leading meta-approach to entrepreneurship that helps us to understand an entrepreneur's actions and action-related beliefs (Frese, 2009). Entrepreneurship not only involves risk-taking, uncertainty, creativity, leadership and proactivity, but also requires persistence and passion. For all these factors, ESE is highly relevant. As such, ESE has emerged as a key psychological construct in entrepreneurship research (Miao et al., 2017), having been found to influence entrepreneurial motivation, intention, behavior and performance, as well as being a critical target outcome of entrepreneurship training and education. Moreover, due to the growing influence of entrepreneurial thinking and acting on career development and vocational behavior (Obschonka et al., 2017), the specific topic of ESE is also becoming increasingly relevant to career researchers, educators and policy makers (World Economic Forum, 2009).

Entrepreneurial self-efficacy is a well-established cognitive antecedent of entrepreneurial behavior, including venture initiation and entrepreneurial performance (Laviolette et al., 2012). For example, it has been found to be positively related to entrepreneurial intentions (Prabhu et al., 2012); outcomes of entrepreneurial education (Edelman et al., 2008); and the entrepreneurial performance among both habitual and nascent entrepreneurs (Miao et al., 2017). Entrepreneurial self-efficacy is an example of a domain-specific application of self-efficacy and is defined as an individual's self-confidence in their ability to successfully perform entrepreneurial roles and tasks (Chen et al., 1998). It is influenced by human capital such as prior experience and education (Zhao et al., 2005). Building upon this idea, Forbes (2005) argued that understanding ESE is important "because it can affect individuals' willingness to engage in entrepreneurship as well as the behavior of those who are already entrepreneurs."

2.3. University environment

The role of universities is decisive in a knowledge-based economy, as they support the generation, exploitation, and expansion of knowledge through education, research, and entrepreneurial activities (Rˇaulea et al., 2016). Also, they add value to society through the transformation of knowledge into social and economic development (Guerrero & Urbano, 2015).

Bearing in mind that knowledge is fundamentally created and transferred in universities, there have been calls in recent years from both governments and society in general for alternative models in which universities contribute more to regional development through entrepreneurial capital and the promotion of entrepreneurial activities (Gaj´on-G´omez, 2016).

Specific training in entrepreneurship is one of the most deeply analyzed determining factors within the field of entrepreneurship (Walter & Block, 2016). In the hope of encouraging entrepreneurship, many universities have developed educational offerings and training courses in this field (Walter & Block, 2016). This trend is not only fed by the recognition of entrepreneurship as an important generator of economic growth, innovation, and employment (Audretsch et al., 2012) but also by the different sources that affirm that both general and specific education in entrepreneurship can play a vital role in the development entrepreneurs (as it allows students to reinforce their entrepreneurial skills and abilities), as well as increasing the rate of entrepreneurial activity (Hechavarría, 2016).

In fact, the university environment has been conceptualized as the set of perceptions of individuals about the degree to which entrepreneurial behavior—such as the search for business

opportunities, the development of new business ideas, the start-up of a new company, or other types of business conduct (Bergmann et al., 2018)—is encouraged, rewarded, and supported in the university environment. In this regard, Goetz and Freshwater (2001) suggested that environment may be an important factor in stimulating entrepreneurial activity while Franke and Lüthje (2004) found empirical evidence of the positive influence of the entrepreneurial university environment on students' entrepreneurial behavior, although, due to its shared nature, the organizational climate is an attribute of organizations or subunits of organizations rather than of individuals (Glick, 1985).

Entrepreneurial career choice may be influenced by how students perceive entrepreneurship to be legitimately accepted at university (Oftedal et al., 2018).

An institutional element within the university that will probably have a strong effect on entrepreneurial behavior is the cognitive dimension (Oftedal et al., 2018), referring to current knowledge and skills and potential access to them. In this sense, courses dedicated to raising awareness of the importance of entrepreneurship and advising students (Rasmussen & Borch, 2010). Thus, universities in a large number of countries have changed their strategic behavior and increased their educational programs in entrepreneurship (Martín et al., 2013) to take advantage of these synergies and become what Etzkowitz et al. (2000) call the "entrepreneurial university." This kind of university is characterized, among other factors, by its members having greater probability of becoming entrepreneurs and, in addition, of follow ing an entrepreneurial pattern at an organizational and contextual level (Guerrero & Urbano, 2012).

Based on the foregoing, we believe that entrepreneurial knowledge derived from a general training and university environment oriented toward entrepreneurship has a positive impact on behavior (Sommer & Haug, 2011) and, therefore, that it is reasonable to expect that:

Hypothesis 1: Positive appraisal of university environment positively correlated with a heightened level of entrepreneurial self-efficacy among students.

3. DATA AND METHODOLOGY

3.1. Sampling

The data comes from the GUESSS survey of 2016, 2018 and 2021 ('Global University Entrepreneurial Spirit Students' Survey'). The GUESSS project is coordinated at global level by the Swiss Research Institute of Small Business and Entrepreneurship at the University of St. Gallen (KMU-HSG) in Switzerland. The students reached by the survey belong to different fields of study (i.e., business and economics, natural and social sciences) and different education levels (undergraduate, graduate and doctoral studies). The survey was conducted at state and private universities in Republic of North Macedonia. A sample of 449 respondents was collected in three research period.

3.2. Measures

3.2.1. Dependent variable

The entrepreneurial self-efficacy is calculated as a mean of the values appointed for each of the following 7 items measured on a 7-point Likert Scale of agreement: Identifying new business opportunities; Creating new products and services; Managing innovation within a business; Being a leader and communicator; Building up a professional network; Commercializing a new idea or development; Successfully managing a business.

3.2.2. Independent variables

The university environment is calculated as a mean of the values appointed for each of the following 3 items measured on a 7-point Likert Scale of agreement: The atmosphere at my university inspires me to develop ideas for new businesses; There is a favorable climate for becoming an entrepreneur at my university; At my university, students are encouraged to engage in entrepreneurial activities.

The following statistical analyses were used:

-Cronbach's Alpha was employed as a method of assessing reliability by comparing the amount of shared variance, or covariance, among the items making up the instruments to the overall variance. Table 1. is presenting the results for the three measured period.

Table 1. Cronbach's Alpha for the construct of Entrepreneurial self-efficacy and university environment for the measured periods

0,92857	1,80E-05	0,00025		
F(t)	f(t)	λ(t)		
0,63212	9,81012E-05	0,00027		
0,9807	2,66632E-05	0,00138		

The Cronbach's Alpha results for the 7 items measuring Entrepreneurial self-efficacy in all three measured periods indicate excellent internal consistency, suggesting that Entrepreneurial self-efficacy is highly reliable across the years 2021, 2018, and 2016. Similarly, the Cronbach's Alpha values for the University environment, measured through the 3 items across the years 2021, 2018, and 2016, also demonstrate excellent reliability and internal consistency (Picture 1)

Cronbach's alpha	Internal consistency
$\alpha \geq 0.9$	Excellent
$0.9 > \alpha \geq 0.8$	Good
$0.8 > \alpha \geq 0.7$	Acceptable
$0.7 > \alpha \geq 0.6$	Questionable
$0.6 > \alpha \geq 0.5$	Poor
$0.5 > \alpha$	Unacceptable

Picture 1. Internal consistency of the value ranges of Cronbach's Alpha (source: https://datatab.net/tutorial/cronbachs-alpha)

4. RESULTS AND DISCUSSION

The measure for entrepreneurial self-efficacy and university environment are calculated as a mean value of previously stated items accordingly. In Table 2. are shown the descriptive analytics for the constructs and items.

Table 2. Descriptive analytics for the constructs and items

Year	Descriptive statistics	Entrepreneurial self-efficacy	Identifying new business opportunities	Creating new products and services	Managing innovation within a business	Being a leader and communicator	Building up a professional network	Commercializing a new idea or development	Successfully managing a business	University environment	The atmosphere at my university inspires me to develop ideas for new businesses.	There is a favorable climate for becoming an entrepreneur at my university.	At my university, students are encouraged to engage in entrepreneurial activities.
2021	Mean	4.94	4.89	4.8	4.76	5.36	4.83	4.91	4.93	4.34	4.33	4.31	4.32
	Minimum	1	1	1	1	1	1	1	1	1	1	1	1
	Maximum	7	7	7	7	7	7	7	7	7	7	7	7
	Standard Deviation	1.469	1.519	1.683	1.778	1.703	1.696	1.766	1.839	1.887	2.05	1.997	1.966
	Valid N	98	98	96	97	97	96	96	97	98	98	97	97
2018	Mean	5.12	4.84	4.84	4.99	5.46	5.21	5.2	5.3	4.71	4.8	4.44	4.85
	Minimum	1	1	1	1	1	1	1	1	1	1	1	1
	Maximum	7	7	7	7	7	7	7	7	7	7	7	7
	Standard Deviation	1.226	1.412	1.402	1.404	1.48	1.44	1.452	1.523	1.505	1.671	1.722	1.733
	Valid N	244	239	237	236	237	238	238	239	244	244	238	236
2016	Mean	5.33	5.07	5.04	5.3	5.85	5.46	5.34	5.5	4.6	4.76	4.18	4.83
	Minimum	1.57	1	1	1	2	1	1	1	1	1	1	1
	Maximum	7	7	7	7	7	7	7	7	7	7	7	7
	Standard Deviation	1.189	1.443	1.365	1.441	1.269	1.448	1.425	1.414	1.779	1.92	1.911	1.934
	Valid N	107	106	105	105	105	104	104	104	107	106	106	105

- Pearson Correlation was used to determine the correlation between the dependent and independent variables. Table 3. is presenting the results for the three measured period.

Table 3. Pearson Correlation among Entrepreneurial self-efficacy and University environment for 2021, 2018, 2016

		Correlations	University environment	
2021	Entrepreneurial self-efficacy	Pearson Correlation	.423**	** Correlation is significant at the 0.01 level (2-tailed).
		Sig. (2-tailed)	0.00	
		N	98	
2018	Entrepreneurial self-efficacy	Pearson Correlation	.229**	** Correlation is significant at the 0.01 level (2-tailed).
		Sig. (2-tailed)	0.00	
		N	244	
2016	Entrepreneurial self-efficacy	Pearson Correlation	0.176	Correlation is not significant at the 0.01 level (2-tailed).
		Sig. (2-tailed)	0.07	
		N	107	

The results of the study indicate a significant correlation between positive appraisal of the university environment and entrepreneurial self-efficacy among students, as measured in three survey periods: 2021, 2018, and 2016.

In 2021 and 2018, the data shows a significant positive correlation between positive appraisal of the university environment and entrepreneurial self-efficacy. This means that as students perceive a more supportive and encouraging environment for entrepreneurship at their university, their confidence and ability to engage in entrepreneurial activities increase.

Therefore, the null hypothesis, which stated that there is no correlation between these factors, is rejected for these two years.

Conversely, in 2016, there is no significant correlation between positive appraisal of the university environment and entrepreneurial self-efficacy. This suggests that during this period, the university environment did not have a substantial influence on students' entrepreneurial self-efficacy. Thus, the null hypothesis is accepted for 2016.

Overall, the findings highlight the importance of the university environment in fostering entrepreneurial self-efficacy among students, but also suggest that the impact of this environment may vary over time.

The results implicate entrepreneurial university environment have a significant positive effect on the entrepreneurial self-efficacy and the results are consistent with previous research findings.

Universities can assist in establishing a more entrepreneurial mind-set among students, which will assist them to re-adjust their expectation of the job market (Wong, et. al, 2007). Formal (individual development process) and informal approaches (work-related context which is considered to be a collaborative process) contribute in different ways to the development of enterprising students, both within and outside university settings (Matlay, 2011).

5. CONCLUSION

The purpose of this study is to determine the positive assessment of the entrepreneurial university environment on entrepreneurial self-efficacy. The findings indicated a significant correlation in 2018 and 2021 regarding the university atmosphere and favorable climate inspiring students to develop new ideas and encouraging and engaging them in entrepreneurial activities. This finding suggests that universities should focus on fostering a supportive environment that encourages students to take control of their entrepreneurial careers. The research showed that the entrepreneurial university environment has a positive effect on entrepreneurial self-efficacy in terms of identifying new business opportunities, creating new products and services, managing innovation within a business, being a leader and communicator, building up a professional network, commercializing a new idea or development and successfully managing a business. This finding underscores the importance of promoting entrepreneurial self-efficacy and a sense of control among students to fully realize the benefits of entrepreneurship education. Although in 2016, there is no significant correlation between the positive evaluation of the university environment and entrepreneurial self-efficacy, in general, the findings show the importance of the entrepreneurial university environment, which in this case becomes more significant over the years.

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Original research

THE GRANGER CAUSALITY OF DIGITAL CONNECTIVITY AND TRADE GLOBALIZATION IN THE HEALTH CRISIS

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Abstract: The widespread adoption of digital technology in the last decade has caused global changes, leading to the belief that technology is altering the global connectivity of economies. This is especially emphasized in light of the global health crisis in 2020. To efficiently monitor this process, it is vital to assess the anticipatory potential of this type of digital connectivity and the growth of globalization in trade. An effective analysis of this issue necessitates looking into the causative relationship between digital technology connections and trade globalization. This is performed by applying the statistical approach of Granger causality to a data set consisting of 35 European countries from 2010 to 2022. A Granger causality study was performed using the lag value estimated based on the Akaike information criterion, which equals 2. The findings suggested that there is a unidirectional causal relationship between active mobile-broadband subscriptions and imports, with the former influencing the latter. However, this causal relationship fails to be valid in the opposite direction. The examination revealed a reciprocal relationship between fixed-telephone subscriptions and exports, as well as a reciprocal relationship between fixed-telephone subscriptions and imports. The results reveal the bidirectional value of the number of fixed telephone subscriptions as a measure of digital connectivity.

Keywords: digital technology, import, export, crisis, causality.

1. INTRODUCTION

The globalization boom began in the 1980s, with developing countries opening to Western markets and expanding foreign direct investment (FDI) (Ari, 2020). Globalization is based on global trade openness and significant financial integration, which is why highly globalized economies are more vulnerable to global market changes than closed countries (Candelon et al., 2020).

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Digital technology, as an important factor in global economic integration, can be considered the driver of globalization development in the 21st century (Baldwin, 2018). Its role in developing society and the economy during the previous decade was critical. This primarily refers to the importance of digital technology, which was highlighted during the period of the global health crisis that began in Europe in 2020 and whose economic consequences are still present and manifest some common features like uncertainty, economic recession, and monetary and fiscal responses (Jebabli et al., 2021).

One of the visible social and economic consequences of the world health crisis was the stagnation of the flow of people, goods, and services beyond national borders. This stagnation resulted in a serious economic slowdown due to the collapse of economic activities, slowed globalization, and reduced the level of international trade activities (Galindo-Martín et al., 2021). Various prohibitions and rules individually adopted by the countries further complicated trade in goods (Liu et al., 2021). The pandemic has imposed restrictions on global trade and the global value chain, particularly for countries that rely on exports (Naseer et al., 2023). Economies have suffered serious fluctuations on the supply and demand sides, and those kinds of market irregularities threaten the speed of recovery after the crisis (Naseer et al., 2023).

Authors Paul et al. (2021) identified the major challenges in the supply chain that can occur during a pandemic, and among the top five challenges they cite are a lack of either financial or other resources, the global recession, a demand decline, a reduction in sourcing options; and an increase in the price of raw materials. Authors Eichengreen et al. (2021) present recent comprehensive research about previous crises and COVID-19, providing a good review of past crisis experiences and attempting to illustrate it with the example of the current crisis. Their study's empirical evidence recalls past crises' challenges and recovery patterns from the 1950s until the current pandemic. However, the main difference between COVID-19 and previous crises is that financial crises start in the financial sector and spread to other sectors. In contrast, health crises emerge in the health sector, hitting other sectors like transport and industry and consequently destroying the financial sector (Jebabli et al., 2021).

Considering the effect of the global health crisis on the scale of worldwide trade as well as the demonstrated value of digital technology during that period, it is vital to investigate the source of these relationships. This study's value lies in exploring the causal relationship between digitalization and globalization, viewed as a share of countries' trade in gross domestic product (GDP). This analysis will enhance the accuracy in predicting the evolution of these phenomena, especially in the dynamic context of the health crisis. The lack of literature on the causal relationship between these two variables throughout the period, including the years before and after the health crisis, motivates this investigation. We applied the Granger-Causality analysis in this research to investigate the causal relationship between digitalization and globalization in trade. The paper's findings should support policymakers, managers, and trade professionals in making rational choices regarding formulating and implementing strategies that would accelerate economic recovery and reinforce global trade.

The paper has five sections. The first section offers an introduction, while the second section discusses the findings from recent literature. The third section provides an overview of secondary data used for analysis and describes the approach that was applied. The fourth section covers the essential study findings and their further evaluation. The final section represents the conclusion. This section summarizes the results, describes the limitations of the research, and offers a brief summary of potential future studies.

2. LITERATURE REVIEW

The study by Skare and Soriano (2021) demonstrates the complex dynamics of the relationship between the adoption of digital technology and globalization. Through Granger causality analysis, it is proven that the growth of globalization directly influences the rising use and acceptance of digital technology, which in turn impacts the further advancement of globalization. Empirical research evaluating digitalization's effects on participation in international distribution chains due to globalization has validated previous results (Gopalan et al., 2022). The research confirms that website accessibility and high-speed Internet availability stimulate business involvement in global supply chains (Gopalan et al., 2022). Applying digital technologies, such as the Internet, helps export growth while minimizing expenditures related to transactions and interactions with partners abroad (Visser, 2019).

Early research performed on panel data from 151 countries in the period from 1990 to 2006 suggests that the use of the Internet as a proxy for digitalization has effects on foreign service trade volume and, therefore promotes the expansion of globalization (Choi, 2010). According to Kere and Zongo (2023), the increasing adoption of ICT in sub-Saharan Africa causes modifications in the import and export rates of goods and services. The researchers discuss that the digitalization of information and processes in the international customs system, along with the development of digital infrastructure through greater penetration of optical fibre, will improve trade turnover while cutting the costs related to foreign trade transactions (Kere & Zongo, 2023). Bunje et al. (2022) study tackles the question of digital technology use in the economy and its effects on trade, which is expressed as the ratio of imports and exports as a share of gross domestic product (GDP). The study confirms that digital technology significantly impacts international trade in both long-term and short-term economic contexts (Bunje et al., 2022). The authors suggest prioritizing the construction of broadband infrastructure and the creation of digital platforms for e-trade (Bunje et al., 2022). Using machine learning methods on a sample of 30 Chinese provinces from 2000 to 2018, another study proved internet use's positive impact on the value of export activities (Shetewy et al., 2022). Another study, which appeared in 2023, examines the effect of internet connectivity on international trade from the perspective of the gravity model (Herman & Oliver, 2023). This research confirms the presence of a correlation between internet usage and international trade, indicating that the Internet supports foreign trade activities (Herman & Oliver, 2023).

A literature review provides evidence about the reverse causality between trade globalization and the adoption of digital technology. In a causal analysis conducted by Grossman & Helpman (1995), the bidirectional causality between digital technology and international trade has been verified. An early study conducted in 2011 confirms the causality between export activities and technology adoption (Bustos, 2011). However, the results of the latest research studies show the bidirectional relationship between digital technology broadband and connectivity and trade openness has been confirmed in a sample of G20 economies (Arvin et al., 2021). The study verifies a bidirectional causal relationship between the number of mobile phone subscriptions, individuals using the Internet, secure Internet servers, fixed broadband subscriptions, and the constructed ICT index as proxies for digital development and, on the other side, trade openness (Arvin et al., 2021). In addition, the study confirms a unidirectional causal relationship between trade openness and the number of fixed telephone subscriptions (Arvin et al., 2021). The authors suggest that promoting the use of digital platforms in foreign trade business can foster transparent and fair trade (Arvin et al., 2021). Research examining the

reciprocal relationship suggests that engaging in a worldwide supply chain affects the integration of digital technologies (Delera et al., 2022). Another empirical study presented in 2022 discusses the Granger causality test results between trade openness, ICT index, and economic growth on a sample of 14 industrial sectors in Tunisia acquired from 1995 to 2018 (Dahmani et al., 2022). The research provides evidence of the bidirectional relationship between the ICT index and trade openness. The authors suggest developing digital infrastructure and sharpening digital skills (Dahmani et al., 2022).

When discussing the effects of the global health crisis, economies that base their development on demand-led growth are the most vulnerable during a crisis, and this state results in an economic recession, which is followed by additional financial constraints such as borrowing restrictions and decreasing purchasing power (Lacerda, 2019). After the global health crisis, the worldwide supply chain can be improved through the expansion of digital technology adoption and trade partnerships, especially between capital-intensive industrialized economies (Liu et al., 2024). Peng et al. (2024) studied the causal relationship between the global health crisis and trade in the form of equity. The authors propose a set of fiscal and economic measures to stabilize the market, including reducing the tax burden, implementing social security programs, and cutting the interest rate on loans (Peng et al., 2024).

3. DATA AND METHODOLOGY

In order to test the causal relationship between the type of digital connectivity and trade globalization, the research study included annual panel data for 35 European countries that were available in the selected data repository. The full list of countries, including EU and non-EU member states, is documented in Table 1. The period covered in the research is 2010 to 2022.

Table 1. List of countries

Austria	Denmark	Iceland	Montenegro	Serbia
Belarus	Estonia	Ireland	Netherlands	Slovak Republic
Belgium	Finland	Italy	North Macedonia	Slovenia
Bulgaria	France	Latvia	Norway	Spain
Croatia	Germany	Lithuania	Poland	Sweden
Cyprus	Greece	Luxembourg	Portugal	Switzerland
Czech Republic	Hungary	Malta	Romania	United Kingdom

Regarding the set research objective, the data were distributed into two groups that illustrate the types of digitalization and trade globalization. The data gathered for the first four variables represents the type of digitalization, and the following two variables were selected for the presentation of trade globalization. The list of variables is reported in Table 2, with appropriate abbreviations and sources.

Table 2. Variable information.

Group	Variable	Abbreviation	Source
Digital connectivity	Active mobile-broadband subscriptions per 100 inhabitants	*AMBS*	World Bank open data (2023)
	Fixed broadband subscriptions per 100 inhabitants	*FBS*	
	Mobile-cellular subscriptions per 100 inhabitants	*MCS*	
	Fixed-telephone subscriptions per 100 inhabitants	*FTS*	
Trade globalization	Import of goods and services as % of GDP	*IMP*	
	Export of goods and services as % of GDP	*EXP*	

The research's analytical component contains the application of econometric analysis using the Granger causality test. Author Clive Granger first described the theoretical broadness of the Granger causality analysis and introduced the technique (Granger, 1969). The Granger causality analysis method analyzes the causal relationship between variables in time series data (Shojaie & Fox, 2022). This analysis suggests that if the past value of the first variable provides a better prediction of the second variable than the past values of the second variable, it is Granger-caused (Granger, 1969). The nature of this relationship might be either unidirectional or bidirectional, depending on the causal directions between the variables. If the values of the first variable are used in predicting the values of the second variable, but there is no realization of reverse causality, then it can be described as a unidirectional causal relationship (Granger, 1969). If a causal relationship can be established between two variables in both directions, then the relationship is considered to be bidirectional causal (Granger, 1969).

When conducting a time series analysis, it is crucial to ascertain the presence of a trend in the data by assessing the stationarity of the data (Shojaie & Fox, 2022). The unit root test assesses the stationarity of panel data (Kónya, 2004). Several tests are available for measuring the unit root, including the Im, et al., (2003), test the Fisher ADF test (Dickey & Fuller, 1979), and the Fisher PP test (Phillips & Perron, 1988). The mathematical calculation of stationarity is performed for data at the level as well as for the first and second differences. Within the test structure, it is possible to include intercept values as well as intercepts with a trend. The lag length is selected according to the available information criteria when doing the unit root test. Practitioners commonly use the following criteria: (1) the Akaike Information Criterion; (2) Schwarz Information Criterion; and (3) the Hannah Quinn Criterion (Bierens, 2004). The null hypothesis for testing stationarity suggests that variable *X* exhibits the presence of a unit root (Kwiatkowski et al., 1992).

Differentiation is performed if the null hypothesis is rejected (Kónya, 2004). The following criteria guide the selection of the lag length value before conducting the Granger causality test (Bierens, 2004; Clarke & Mirza, 2006; Hatemi-J & Hacker, 2009):

1. *LR*: The sequential modified LR test statistic is used at a 5% significance level for each test.
2. *FPE*: Final prediction error is a measure used for prediction accuracy.
3. *AIC*: The Akaike information criterion is a statistical measure used for model selection.
4. *SC*: The Schwarz information criterion is another statistical measure used for model selection.
5. *HQ*: The Hannan-Quinn information criterion is another statistical measure used for model selection.

The slope with the lowest value, given by most criteria, is selected. Afterwards, the data points are arranged to undergo Granger analysis. The null hypothesis being examined can be presented in the following form (Granger, 1969):

H0: Previous values of variable X do not offer any additional insight in forecasting future values of variable Y than the past values of Y.

The decision involving causality is made based on the findings of the evaluated assumptions.

4. RESULTS AND DISCUSSION

The descriptive statistical measures presented in Table 3 provide insight into the characteristics of the data set. Spanning a total series of 455 observations, it becomes evident from the minimum and maximum values that substantial disparities exist in the attained values

across the observed countries. This variability is particularly pronounced in the variable denoting active mobile broadband subscriptions, wherein data dispersion around the mean is most pronounced, reflecting the high variance.

Table 3. Descriptive statistics.

Variable	Minimum	Maximum	Mean	Std. Deviation	Variance
AMBS	8.00	210.00	80.61	35.1392	1234.76
FBS	10.00	50.00	30.96	8.2011	67.26
MCS	87.00	203.00	123.33	16.5607	274.26
FTS	3.00	96.00	34.51	15.5603	242.12
IMP	26.00	180.00	61.65	29.4363	866.49
EXP	22.00	213.00	64.04	34.8347	1213.46
Valid N = 455					

The basic step in analyzing the times series is related to verifying the stationarity of the data set. The stationarity of the data was checked using the panel unit root analysis based on the test developed by Im et al. (2003). This type of test was selected because it considers the presence of heterogeneity among the data reflected in observing different countries (Antonietti & Franco, 2021). The latency length was assumed to be 2 when conducting this test, as suggested by the Akaike Information Criterion (AIC). This is also the typical value applied when analyzing annual data, as in this example. The results of the unit root test are shown in Table 4.

The stationarity check led to the conclusion that all variables, except for active mobile broadband subscriptions (*AMBS*), lack stationarity. The authors applied the mathematical calculation of the first difference between the values of the provided variables to address this problem and transform all non-stationary variables into stationary ones. The outcomes presented in Table 4 illustrate the Im, Pesaran, and Shin tests after the first difference calculation. Before conducting the Granger causality test, standard vector autoregression estimates (VAR) were used to examine the value of the lag length based on six endogenous variables. Table 5 presents the results of the VAR analysis, encompassing all six information criteria used to measure the lag length.

Table 4. Im, Pesaran and Shin unit root test.

Variable	Level		1st difference	
	Intercept	Intercept and trend	Intercept	Intercept and trend
AMBS	0.0000	0.0055	0.0000	0.0000
FBS	0.9045	0.8897	0.0000	0.0000
MCS	0.2985	0.3815	0.0000	0.0000
FTS	0.2106	0.0000	0.0000	0.0000
IMP	0.9936	0.0035	0.0000	0.0000
EXP	0.8068	0.0014	0.0000	0.0002

Table 5. VAR Lag order selection criteria.

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-6284.323	NA	164000000	35.94471	36.01084	35.97103
1	-5768.448	1011.116	10589035	33.20256	33.66551*	33.38683
2	-5699.994	131.8224*	8798154.*	33.01711*	33.87688	33.35933*

* indicates lag order selected by the criterion

LR: sequential modified LR test statistic; FPE: Final prediction error; AIC: Akaike information criterion; SC: Schwarz information criterion; HQ: Hannan-Quinn information criterion.

In most cases, the selected value of the length of the lag is 2, which is the adopted value for further pairwise Granger causality analysis, and the analysis outcome is presented in Table 6.

Table 6. Pairwise Granger Causality Tests, lags: 2.

Null Hypothesis:	Observations	F-Statistic	Probability (*p*-value)
Δ*IMP* does not Granger Cause *AMBS*	350	1.41113	0.2453
AMBS does not Granger Cause Δ*IMP*		4.58984	0.0108
Δ*EXP* does not Granger Cause *AMBS*	350	0.27414	0.7604
AMBS does not Granger Cause Δ*EXP*		2.05075	0.1302
Δ*IMP* does not Granger Cause Δ*FBS*	350	0.89242	0.4106
Δ*FBS* does not Granger Cause Δ*IMP*		0.78035	0.4591
Δ*EXP* does not Granger Cause Δ*FBS*	350	0.78664	0.4562
Δ*FBS* does not Granger Cause Δ*EXP*		1.65447	0.1927
Δ*IMP* does not Granger Cause Δ*MCS*	350	0.92681	0.3968
Δ*MCS* does not Granger Cause Δ*IMP*		1.25544	0.2862
Δ*EXP* does not Granger Cause Δ*MCS*	350	1.99499	0.1376
Δ*MCS* does not Granger Cause Δ*EXP*		0.11339	0.8928
Δ*IMP* does not Granger Cause Δ*FTS*	350	5.08357	0.0067
Δ*FTS* does not Granger Cause Δ*IMP*		5.44011	0.0047
Δ*EXP* does not Granger Cause Δ*FTS*	350	4.67553	0.0099
Δ*FTS* does not Granger Cause Δ*EXP*		3.94448	0.0202

Using pairwise Granger causality analysis, researchers found both one-way and two-way links between different aspects of digital connectivity and globalization in trade. A statistically significant unidirectional connection was observed from the variable of active mobile broadband subscribers (*AMBS*) to the import variable (*ΔIMP*) ($p < 0.05$). Specifically, the number of active mobile broadband customers can serve as an indicator for anticipating fluctuations in imports because any change in the number of mobile users leads to a change in import balance. The inverse relationship of this relationship was not validated, indicating that the statistics on imports do not significantly impact the estimation of the number of active mobile broadband customers. The Granger causality test could not detect any statistically significant causal links between the export variables (*ΔEXP*) and active mobile broadband subscribers (*AMBS*). No causal relationship was found between fluctuations in imports (*ΔIMP*) and exports (*ΔEXP*) in connection with variations in the number of fixed broadband subscribers (*ΔFBS*) and mobile cellular subscribers (*ΔMCS*). These findings demonstrate that the data on imports and exports does not impact the number of fixed broadband users or mobile cellular subscribers. As a result, they cannot be utilized to forecast future values in either direction. Conversely, the positive outcomes of the Granger test demonstrated a bidirectional connection between imports (*ΔIMP*) and fixed telephone subscribers (*ΔFTS*), as well as between exports and fixed telephone subscribers (*ΔFTS*), with statistical significance ($p < 0.05$). The results of the study of the Granger causality test suggested that the use of fixed telephones as a form of digitalization has a causal effect on the fluctuations in imports and exports of the countries under investigation and vice-versa. Through that connection, the relationship reflects control and management of the flow of goods and services in international trade. The bidirectional causality results align with the previous research results (Arvin et al., 2021; Delera et al., 2022; Dahmani et al., 2022). By utilizing these indicators, it is possible to develop more accurate predictive models, as variations in the number of fixed telephones might forecast changes in the trade balance and vice-versa. The results have profound implications for decision-making

based on information and knowledge, indicating that intervening in one variable can also impact other variables.

5. CONCLUSION

When developing a forecasting model to understand the relationship mechanism, it is essential to identify the causal relationship between the variables. This study provides an understanding of the causality between different types of digital connectivity and globalization in trade. It analyses the research problem by applying the generally accepted Granger causality analysis to a dataset spanning 35 European countries between 2010 and 2022.

The paper's scholarly value is found in examining the relationship between different kinds of digitalization and trade globalization, both before and shortly after the emergence of the 2020 global health crisis. It provides essential knowledge into the utilization of these variables for developing prediction models, considering that international trading witnessed a substantial decline during the crisis period due to the stagnation of cross-border trade. Furthermore, digital technology plays an integral part in supporting the integration of the global population.

In addition to its scientific significance, the research study also holds practical value. Causal analysis has proven that mobile technology accessibility can impact import volume. Therefore, improving digital mobile technology can influence the globalization of trade flows, aligning with strategies for future trade development. The growing popularity of mobile telephony has the potential to enhance the efficiency of international trade by facilitating the exchange of goods and services across different e-commerce platforms.

The relationship between the number of fixed telephony customers and imports and exports demonstrates the importance of population and economic integration in global trade flows. Modernizing and broadening the digital infrastructure for fixed telecommunications will be extremely helpful for managing worldwide trade flows. Adopting such guidelines may strengthen the effectiveness of global trade operations and lower trade expenses.

The study's limitations pertain to the data collection time frame, which could expand with historical data availability. Furthermore, the limitation is evident in the selection of variables that depict globalization in trade. Therefore, additional research might incorporate a broader range of these indicators. The final identified limitation is the inability to perform a Granger cause analysis on distinct data sets prior to and following the health crisis. This is due to the small data set size after 2020, which consequently delays the completion of the comparative analysis until a future period.

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DEVELOPMENT AND VALIDATION OF MEASUREMENT INSTRUMENT FOR GREEN KNOWLEDGE MANAGEMENT

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Abstract: Green knowledge management represents a new direction of knowledge management in organizations. As an intensively represented concept, it has awakened the interest of many researchers to examine the cause-and-effect relationships of this concept and related variables. To analyze this concept more deeply using statistical analysis methods, it is necessary to develop an instrument that will be used for measurement and analysis. In this regard, this paper describes the process of developing and validating a measurement scale for comprehensive research on green knowledge management, green technology and innovation, organizational performances, and management commitment to the ecology. Thanks to the analysis results that show that the proposed questionnaire for measuring the mentioned variables is a valid and reliable measurement scale, it can be said that the main motive of the work is fulfilled and that the result of this research has a significant contribution to the growing body of literature.

Keywords: Green knowledge management, questionnaire development, validation and reliability of the measurement scale, statistical analysis

1. INTRODUCTION

In recent decades, organizations have been paying more and more attention to what effects their operations can have on the environment. This issue is becoming a dominant topic in the minds of many managers and employees, as well as other stakeholders. Due to numerous hazardous consequences, which primarily relate to the environment, the concept of knowledge management has acquired a new dimension. One of the most recognizable trends in the field of sustainable business is a greater understanding of environmental problems.

In order for the company to have a balanced approach to the consumer and environmental perspective, the company's employees must have adequate green knowledge (Shehzad et al., 2020). The difference between successful and unsuccessful organizations is precisely knowledge, with special reference to adequate management (Revilla et al., 2016). In this regard, the creation of new products, services, and processes aligned with the needs of sustainable development and environmental requirements represents imperatives of modern

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business. For this reason, a new, upgraded concept called green knowledge management - GKM is emerging. The GKM concept differentiates between environmentally sustainable and unsustainable companies (Khan et al., 2024), directing the company to the path of success, survival, and development.

There is a growing body of academic research investigating the relationship between green knowledge management and organizational performance, sustainability, and innovation. Thus, by analyzing the Scopus database, it can be determined that the number of works on this topic is increasing significantly (Radić et al., 2023). In order to examine the attitudes of employees in organizations related to the newly created GKM concept, there was a need to create a new comprehensive questionnaire.

The motive of this work is the development and validation of a measuring instrument that connects GKM, green technologies and innovations (GTI), management commitment to ecology (MCEE), and organizational performance (OP). The potential contribution of the results of this study is reflected in the validation of a new measurement instrument that can be used for the comprehensive measurement of GKM and related areas.

This paper is divided into several units. After the introductory part, there follows the second part, which refers to the literature review with the presentation of the theoretical background of the problem. In the third part, the research methodology is presented with the research steps described in detail. The following sections refer to the research results and discussion, as well as the conclusion, respectively.

2. LITERATURE REVIEW

The concept of GKM is of great importance for the operations of organizations by the requirements for sustainable principles. It strives for the integration of ecological aspects in the process of organizational learning and the introduction of sustainability principles into the dimensions of the previous classic concept of knowledge management (Aboelmaged & Hashem, 2019). This is the proactive paradigm necessary to manage organizational success in a competitive market. For the company to succeed in its efforts to adapt to the new environmental requirements of the environment, the company must find channels through which it can collect the necessary knowledge (Arfi et al., 2018), and then store it (Pepple et al., 2022) and use it, i.e. share (Song et al., 2020). In this connection, it is possible to talk about three related dimensions of green knowledge management, namely green acquisition, green storage, and green sharing.

Green products and green processes must be based on knowledge, so green knowledge is closely related to GTI. GTI can be defined as products, services, and processes that do not harm the environment or reduce its degradation (Ahmed et al., 2023). According to Ciu et al. (2021), GTI represents a corporate strategy that is implemented at the level of the organization, but in such a way that it contributes to the aspirations for the recovery of the environment at the global level. Xie et al. (2019) state that this approach to combining green products and processes leads to the creation of a strategic advantage that is difficult to imitate. Considering this fact, in this paper green products and green processes are presented as a single variable.

On the other hand, one of the most important priorities of any organization is its performance. According to Arfa et al. (2018) performance effects can be measurable (profit, ratios, etc.) and immeasurable (reputation, contribution to environmental protection, green brand, etc.). For this reason, in the concept of GKM, organizational performance can combine environmental performances and economic performances. Based on the above, in this paper, the economic and environmental indicators of the business operations of the investigated organizations are observed under organizational performance.

Also, if the leaders of the organization are not aware of the importance of GKM and the contribution that GTI has to OP, the organization cannot implement these practices. Numerous studies have confirmed that it is the management of the company that should be approached as a direction in creating a green organizational culture (Wang, 2019). This is how a new important determinant of GKM is being developed, which is MCEE. Whether the employees will share the same values depends on the management's increase in ecological and sustainable practices. In other words, when upper-level management shows concern for environmental issues, employees will follow suit (Wei et al., 2023).

Based on the review of the relevant literature, it can be concluded that there is a close connection between the mentioned areas of GKM, GTI, OP, and MCEE. In this regard, this paper starts from the observed research gap, which can be explained as the need for the development and validation of a comprehensive measurement scale composed of a set of appropriate questions that can be used to measure the mentioned variables.

3. RESEARCH METODOLOGY

The questionnaire development and validation process involves several stages as shown in Figure 1.

The primary phase was related to the review of relevant literature, through which the basic dimensions of GKM, GTI, OP, and MCEE were identified. In this research, questions from other questionnaires that were validated during previous research were combined, which is a very common practice in the academic community.

After the literature review, pilot testing was performed, which involved testing the initial version of the questionnaire on a sample of 33 respondents. In addition, a check on the clarity and comprehensibility of the questions was made in the discussion with focus groups made up of managers and experts from this field. Also, bearing in mind that the research is being conducted on the territory of Serbia, the translation of the questionnaire from foreign literature and harmonization with the meanings of the Serbian language was done with the consultation of experts. The final version of the questionnaire was used for data collection.

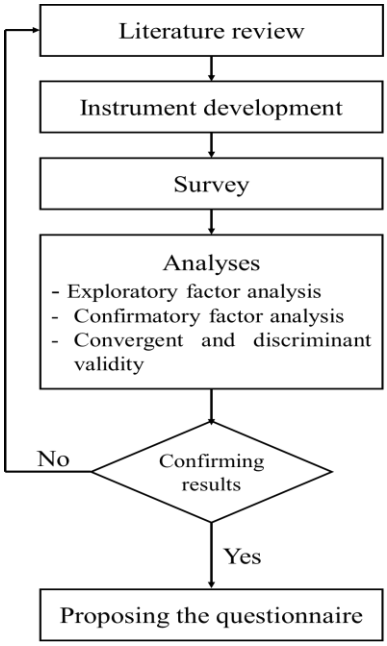

Figure 1. Process of questionnaire development and validation

To take a thorough approach to this analysis, and to make the findings accurate and reliable, exploratory and confirmatory factor analysis, as well as convergent and discriminant validity, were performed. Statistical analysis was performed using SPSS v.18 and AMOS v.26 software packages

4. RESULTS AND DISCUSSION

4.1. Descriptive statistics

The survey included 538 respondents employed in 21 project-based organizations. 66% of men and 34% of women participated in the research. Among the respondents, almost a third of them (32.7%) belong to the age group between 36 and 45 years. The research included respondents with 6 to 10 years of work experience (28.1%). The dominant structure consists of respondents with primary education (71.4%), while 12.8% of respondents have secondary and 14.5% with higher education. The least number of respondents had completed basic academic studies (1.3%), and there were no respondents with a master's or PhD degree.

Table 1. Respondents' demographic data

Variables	Category	N	Percentage (%)
Gender	Male	355	66.0
	Female	183	34.0
Age	Less than 25 years	42	7.8
	26 – 35 years	140	26.0
	36 – 45 years	176	32.7
	46 – 55 years	137	25.5
	More than 56 years	43	8.0
Work experience	Less than 5 years	146	27.1
	6 – 10 years	151	28.1
	11 – 20 years	127	23.6
	21 – 30 years	60	11.2
	Above 31 years	54	10.0
Educational level	Elementary school	384	71.4
	High school	69	12.8
	Higher education	78	14.5
	University	7	1.3
	MSc/PhD	0	0.0
Job position	Manager	45	8.4
	Workers	493	91.6
Company size	Less than 10 employees	28	5.2
	11 – 50 employees	168	31.2
	51 – 250 employees	341	63.4
	Above 251 employees	1	0.2
Company's existence	Less than 6 years	446	82.9
	6 – 10 years	32	5.9
	11 – 20 years	60	11.2
	21 – 30 years	0	0.0
	Above 31 years	0	0.0
Company ownership structure	Domestic ownership	85	15.8
	Foreign ownership	362	67.3
	Mixed ownership	91	16.9

In the research, there were 8.4% of respondents in the position of managers (shift managers, lower and middle management), and 91.6% of employees who are directly involved in the business process. According to the size, the survey covers mostly medium-sized organizations (51-250 employees), as much as 63.4%, and organizations that have been in business for less than 6 years (82.9%). Regarding the company ownership structure, 15.8% of companies are domestically owned, 67.3% are foreign-owned, and 16.9% are mixed.

The complete results of descriptive statistics are shown in Table 1, which offers a clear and detailed picture of the data. By reviewing these statistics, we can better understand the trends and patterns that emerge from the data.

4.2. Exploratory factor analysis

To understand the basic relationship between research and composite variables, exploratory factor analysis (EFA) was conducted. For this analysis, the varimax rotation technique was used in combination with principal component analysis. First, to check the adequacy of the sample using a Kaiser-Meyer-Olkin (KMO) test and Bartlett test of sphericity. In this study, the KMO coefficient is 0.945 (the recommended minimum value is 0.6 according to the authors of Hair et al., 2010), which indicates the suitability of the data for factor analysis. Furthermore, the Bartlett test of sphericity indicates significance (χ^2=13,806; p≤0.001), recommended value p≤0.05, according to the authors Hair et al. (2010). This indicates that there are correlations among the items within the measurement instrument.

According to the EFA results, four factors were extracted that explain 68.90% of the variance of the proposed model, which is by the minimum proposed value of 0.50% (Molina et al., 2007). The coefficients are grouped according to the basic components of the questionnaire (composite variables). This was expected because the items were taken from previously validated and verified questionnaires (see references in Table 2) and adapted to the needs of this research. In the analysis, all items that load one factor 0.4 or above (see Table 2) were retained, based on the recommendation of the author Churchill (1979). Therefore, the results established the unidimensionality of the variables.

Table 2. Measuring instrument and items loading

Code	Items	Factor Loading			
		1	2	3	4
Green knowledge management Yu et al. (2022)					
GKM_1	The organization regularly receives information about environmentally friendly products and processes/services from external stakeholders (e.g. customers and suppliers)	0.868			
GKM_2	The organization regularly receives information about environmentally friendly products and processes/services from internal stakeholders (e.g. management and staff)	0.840			
GKM_3	The organization regularly organizes trainings for employees to develop their knowledge about environmentally friendly products and processes/services	0.831			
GKM_4	The organization has a well-developed information system through which employees can get the necessary information	0.811			
GKM_5	The organization encourages and supports employees to acquire knowledge about environmentally friendly products and processes/services	0.631			
GKM_6	The organization has sufficient information on environmentally friendly products and processes/services	0.951			

GKM_7	The organization has an excellent information system for managing information related to environmentally friendly products and processes/services	0.827			
GKM_8	Information about a specific problem is easily available through our information system	0.815			
GKM_9	We have comprehensive information about our competitors and the environmental impact of their operations	0.748			
GKM_10	Even if someone leaves the organization, our information system retains their knowledge	0.685			
GKM_11	Employees in our organization regularly communicate with each other in order to exchange knowledge and discuss further directions for the development of environmental protection	0.787			
GKM_12	The organization has a well-organized system through which knowledge can be shared and mutual learning can be affirmative	0.776			
GKM_13	The organization has provided the latest equipment and technology for the acquisition and exchange of knowledge	0.762			
GKM_14	The organization recognizes and rewards employees who share innovative ideas and information to improve environmental protection processes	0.733			
GKM_15	The organization regularly shares the latest environmental knowledge and market trends with its employees through e-mails, trainings and workshops.	0.729			
Green technology and innovation Huang & Li (2017)					
Has your organization ever taken the following measures when designing products or processes/services?					
GTI_1	Used environmentally friendly materials (eg less polluting or non-polluting/less toxic or non-toxic materials)		0.882		
GTI_2	Improved and designed environmentally friendly packaging (e.g. less consumption of paper and plastic material) for existing and new products		0.865		
GTI_3	Recycling, reuse and processing of materials at the end of the product's life		0.863		
GTI_4	Used eco-labeling		0.843		
GTI_5	Used lower consumption of energy sources such as water, electricity, gas and gasoline during production/use/disposal		0.838		
GTI_6	Used cleaner technology to save and prevent pollution		0.804		
GTI_7	Reduction or complete elimination of toxicity in the production process		0.774		
Organizational performance Huang & Li (2017); Sahoo et al. (2023)					
Has your organization performed better compared to your main competitors in the following areas?					
OP_1	Operational efficiency			0.887	
OP_2	Sales growth			0.876	
OP_3	Market share growth			0.765	
OP_4	Reductions in consumption of hazardous/harmful/toxic materials			0.741	
OP_5	Profit growth			0.789	
OP_6	Improvements in the environmental situation of the company			0.623	
OP_7	Cash flow			0.654	
OP_8	Reputations in the market			0.684	
OP_9	Market share growth			0.878	
Management commitment to the ecological environment Sahoo et al. (2023)					
MCEE_1	In our organization, there are enough ways to gather green knowledge				0.848

MCEE_2	I have the necessary training in green knowledge management				0.811
MCEE_3	I always get enough knowledge to do my job smoothly				0.798
MCEE_4	Verbal instructions about green knowledge are regularly given to workers				0.765
MCEE_5	My supervisor has the necessary knowledge to overcome environmental risks in business				0.764
MCEE_6	My supervisor always ensures that environmental protection rules and procedures are followed				0.725

Cronbach's alpha test was used to check the internal consistency of the measuring instrument. Composite reliability (Cronbach's alpha) is shown in Table 3.

Table 3. Composite reliability and convergent validity

Construct	Items	Cronbach's alpha	Factor Loading	AVE
GKM	15	0.893	0.631–0.951	0.624
GTI	7	0.929	0.774–0.882	0.704
OP	9	0.858	0.561–0.797	0.596
MCEE	6	0.874	0.725–0.848	0.618

Upon examining the Cronbach alpha test, it is clear that all of the values surpass the recommended minimum of 0.70 (Cronbach, 1951). This indicates that the composite variables have a high level of internal consistency and reliability, and can be used in further analyses.

4.3. Confirmatory factor analysis

Confirmatory factor analysis (CFA) was used to examine the convergent and discriminant validity of the measuring instrument. Convergent validity is assessed by the factor loading of the items, the minimum value of which should be above 0.5 according to Hair et al. (2010). The average variance extracted (AVE) test assesses discriminant validity.

Also, based on the recommendation of Molina et al., 2007, the AVE of all constructs should be above 0.5. As all values are above the recommended value of 0.5 (see Table 3), it can be concluded that the convergent and discriminant validity of the measuring instrument has been achieved. The results presented in Table 3 can be explained as follows. The composite variable GKM contains 15-factor loadings from 0.631 to 0.951. This factor explained 62.40% of the variance with 0.893 Cronbach's alpha value. Analogous to this explanation, the values for the other composite variables (GTI, OP, and MCEE) can also be clarified. Also, CFA allows assessment of the fit of the measurement model, which was done using the AMOS v.26 software package. To determine how well the model fits the data, CFA offers several different statistical tests. Some of them are shown in Table 4.

Table 4. Fit indices

Particulars	χ^2/df	GFI	NFI	AGFI	CFI	SRMR	RMSEA
This model	2.95	0.92	0.90	0.87	0.88	0.78	0.09
Recommended values	≤3[a]	≥0.9[b]	≥0.9[b]	≥0.9[b]	≥0.9[b]	≤0.8[b]	≤0.08-0.10[b]

Notes A: χ^2/df : Chi-square to degree of freedom; GFI: Goodness of fit index; NFI: Normative fit index; AGFI: Adjusted goodness of fit index; CFI: Comparative fit index; SRMR: Standardized root mean residual; RMSEA: Root mean square error of approximation
Notes B: [a]Bagozzi and Yi (1988); [b]Hair et al. (2010)

Based on the CFA results, it is concluded that most of the fit indices are within the recommended values. However, there are some deviations. There is a small deviation in the indicators AGFI (0.87) and CFI (0.88), which can be considered acceptable. In general, it can

be concluded that the model-fit indices have satisfactory values, and it can be considered that the studied model has an acceptable level of fit.

The correlation coefficients of the composite variables are shown in Table 5.

Table 5. Correlation coefficients of composite variables

	GKM	GTI	OP	MCEE
GKM	1			
GTI	0.631	1		
OP	0.679	0.913	1	
MCEE	0.713	0.826	0.838	1

Also, it can be concluded that the correlation coefficients of the composite variables are above the recommended values of 0.3.

Based on the thorough tests and analyses conducted, it can be confidently stated that the proposed measuring scale meets the standard criteria for the instrument. With its accuracy and precision, this measuring scale is sure to provide reliable results for any application.

5. CONCLUSION

Green knowledge signifies a new concept and a new chapter in the discipline of knowledge management. This kind of knowledge is significantly different from the classic concept of knowledge in the organization and is gaining more and more importance in modern business conditions.

This work aimed to develop and validate a comprehensive questionnaire that connects GKM, GTI, OP, and MCEE. Based on the review of the literature, it was observed that these are frequently represented components in various researches in the field of green knowledge.

Bearing in mind the results of the validation of the measuring scale, i.e. the results of EFA and CFA statistics, values were obtained that are within the recommended limits, and it can be concluded that the proposed questionnaire presented in this study represents a reliable and verified measuring instrument.

The implications of this work are reflected in the possibility of applying this measuring instrument, as well as the application of other methods and techniques for further research. Bearing in mind that scientists, academics, and practitioners are very interested in the field of green knowledge, it is expected that the result of this work will produce further research in this field.

The developed and proposed measuring instrument provides a basis for further research and development of various structural models.

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Abstract: The development of family companies can become a driver of the national economy and form mechanisms that overcome foreign economic barriers and political challenges. The purpose of the presented work was to study the dynamics of career preferences of students from Russia and Bulgaria (the comparison was made in 2021 and 2023). This empirical study was conducted within the framework of the InterGen project. The results of the statistical analysis showed that the most desirable thing for students in the two countries is to build their own business. The second most popular is working in a large company. The least attractive is the prospect of creating or continuing a family business. Comparison by year showed that for the University of Ruse the statistical differences are not significant. For University of Tyumen the career orientation "opening a family business" shows a significant decrease. This empirical result may indicate the ineffectiveness of government programs to popularize family businesses in Russia.

Keywords: family business, youth entrepreneurship, career orientations, career prospects, InterGen project.

1. INTRODUCTION

The modern economic and technological development of states cannot be imagined without their participation in global value chains. The development of national economies, ensured by international trade, has historically been accompanied not only by the mutual exchange of new knowledge and technologies, but also by intense competition, expressed by the use of mercantilism, protectionism, systemic measures of government pressure and restrictions in order to protect national interests and the formation of non-economic competitive advantages (Zaikin, 2014).

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In conditions of competition and restrictions imposed on large national enterprises, diversification of the economy is possible through the development of small and medium-sized businesses that have flexibility, the ability to innovate, high speed of response and adaptation to changing market conditions (Kisioglo & Medvedeva, 2023).

Based on a 10-year study in 43 countries, it was found that family entrepreneurship (family firms, companies) on average have higher growth rates (Miroshnychenko et al., 2021), and the presence of formal and informal governance mechanisms contributes to sustainability in times of crisis (Calabrò et al., 2021). A number of studies highlight the strong link between family entrepreneurship and innovation in uncertain times, driven by the desire to maintain the firm as a lifelong endeavor (Leppäaho & Ritala, 2022; Duong et al., 2022).

Taking into account the presented arguments, the development of family companies can become a driver of the national economy and form mechanisms that overcome foreign economic barriers and political challenges.

Next, we present how programs for the development and popularization of small businesses are being implemented in the Russian Federation. At the end of 2018, the National Project "Small and Medium Enterprises and Support for Individual Entrepreneurial Initiatives" began its work, which is aimed at developing all forms of entrepreneurship, including youth and family entrepreneurship. At the same time, it can be noted that work on the development of these types of entrepreneurship is carried out with different intensity.

The development of youth entrepreneurship has been carried out in the Russian Federation since 2016 within the framework of the State Program "Economic Development and Innovative Economy". In addition, the Federal project "University Technological Entrepreneurship Platform" has been implemented since 2022. The federal project includes systemic mechanisms, such as entrepreneurial competency training; "Entrepreneurial boiling points"; University startup studios; University acceleration programs; Grant support for student startup projects; Startup investment reimbursement program for private investors; University venture funds.

In general, Russian experts note the high effectiveness of youth entrepreneurship development measures. According to the Agency for Strategic Research in 2020: 88% of high school students and students wanted to develop a business or were already doing so (Youth Entrepreneurship, 2021). It is no coincidence that in 2021 The minimum age limit for registering as self-employed was lowered (from 18 to 16 years).

Let us now turn to the forms of popularization of family entrepreneurship in the Russian Federation. Recognition of the importance of family business in Russia at the highest level occurred in 2019, when the President of Russia instructed the Chamber of Commerce and Industry of the Russian Federation to consider state support measures for family businesses. By the end of 2023, 5 Family Business Centers were opened, whose tasks include supporting and developing family companies in the regions (Chamber of Commerce, 2023).

With the support of the Chamber of Commerce and Industry, the following programs are being implemented (Chamber of Commerce and Industry, 2024): "100 family companies under the patronage of the President of the Chamber of Commerce and Industry of the Russian Federation"; "100 Business Hopes" for the development of youth entrepreneurship; All-Russian Family Council; All-Russian Forum of Family Entrepreneurship "Successful Family – Successful Russia".

Unfortunately, in the Russian Federation there is still no reliable data on the dynamics of family business development. At the same time, an analysis of news content in the "We Watch" application (federal channel) shows that news reports on family business topics are extremely rare (the last news is dated 10 June 2023). Events hosted by the Chamber of Commerce and Industry are only featured on the Chamber's website.

The purpose of this work is to study the dynamics of career orientations of students from Russia and Bulgaria and to find out how family business is an attractive model of future employment for young people.

Based on the presented provisions, we formulated the hypothesis: family business in the Russian Federation as a form of future employment for young people is less attractive compared to independent business.

2. DATA AND METHODOLOGY

This empirical study was conducted within the framework of the InterGen project aimed at revealing the characteristics of family entrepreneurship in different countries and examining students' attitude to building a joint business with relatives.

The present study examines and compares the results generated for 2021 and 2023 in two of the academic institutions, part of the INTERGEN network: University of Ruse (Bulgaria) and University of Tyumen (Russia).

Table 1. Descriptive characteristics of the sample

	2021	2023
University of Tyumen, Russia	243 people (19% men, 81% women)	245 people (32% men, 67% women)
"Angel Kanchev" University of Ruse, Bulgaria	288 people (22% men, 79% women)	582 people (22% men, 78% women)

These universities have used the questionnaire, developed by INTERGEN in 2021, as they are members of this international academic network. The main purpose of the questionnaire is to study the intergenerational family businesses as a stress management instrument for entrepreneurs. The respondents need to understand the questions, and therefore, each university has translated the questions into the national language of each country. Most of the answers are based on the Likert scale: 1-No; 2-Rather No; 3-N/A; 4-Rather Yes; 5-Yes. The universities collected the answers via Google Forms, which facilitated the statistical analyses.

The study gives priority to the next specific questions:

Question № 2. I prefer to work in a large company.

Question № 3. I would like to have my own business.

Question №29. I would like to have a family business with my relatives.

Statistical analysis was performed using the Statistica 8.0 software package. We applied descriptive statistics and Student's t-distribution to determine the significance of differences.

3. RESULTS AND DISCUSSION

We compared the preferences in career orientations of students at the University of Tyumen and the University of Ruse (Fig. 1) in 2021 and 2023. The most desirable future career option for students in the two countries is to build their own business. The second most popular is work in a large company. The least attractive is the prospect of starting or continuing a family business.

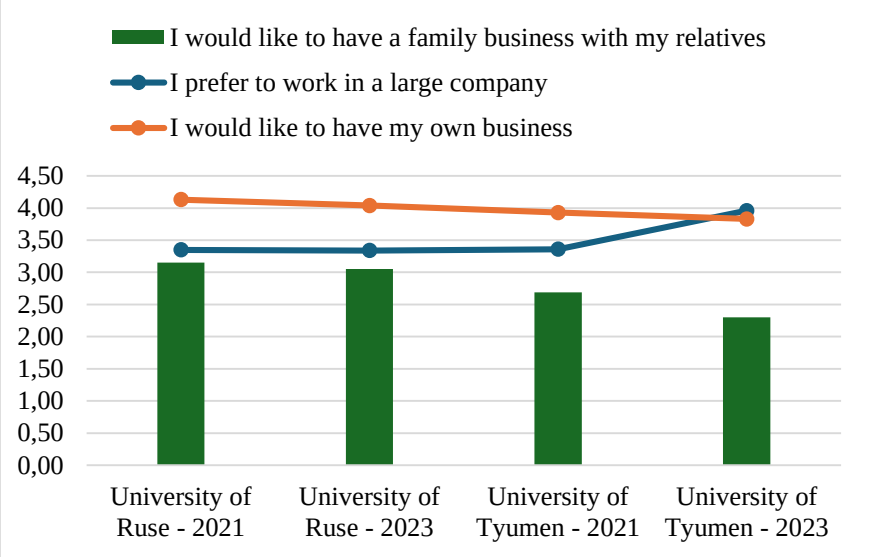

Figure 1. Comparison of average career preferences of students (2021/2023) from University of Ruse and University of Tyumen, points (max=5)

Figures 2 and 3 present the average values and confidence intervals for data from the Russian Federation and Bulgaria.

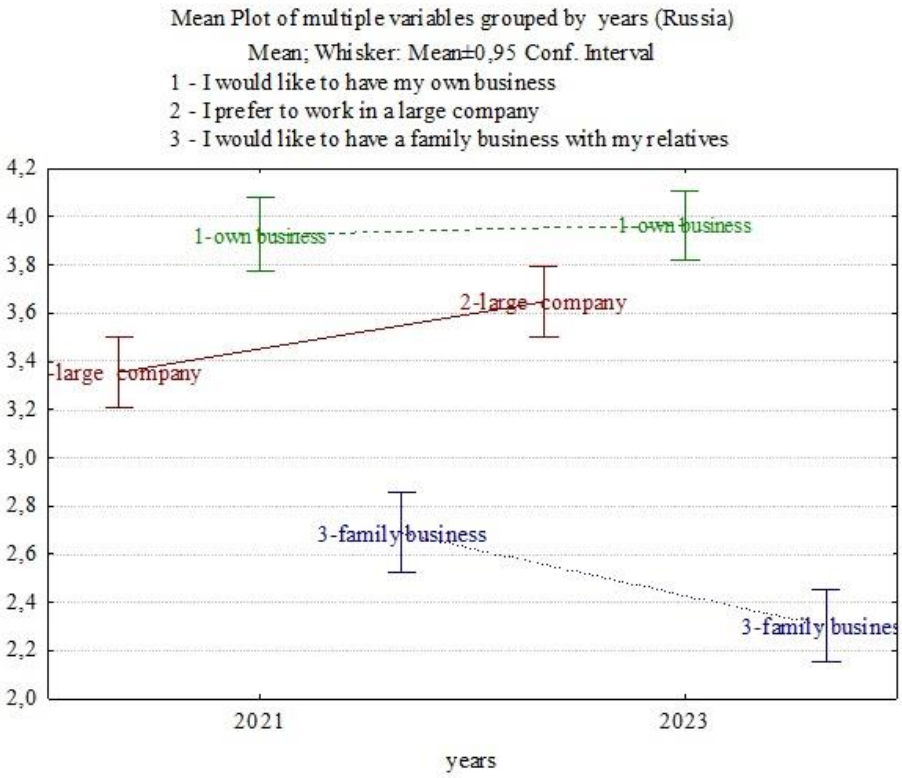

Figure 2. Comparison of average career preferences of University of Tyumen students (2021/2023), points (max=5)

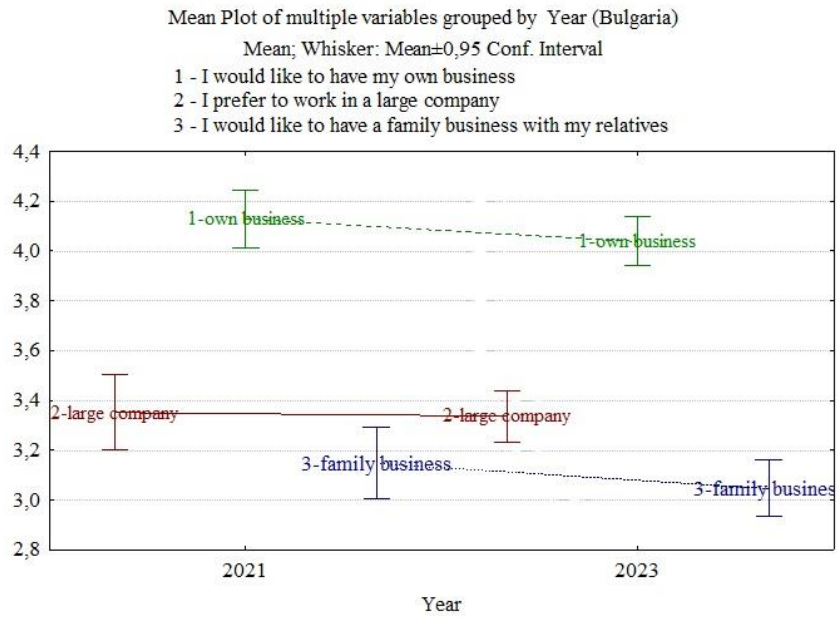

Figure 3. Comparison of average values of career preferences of students (2021/2023) from University of Ruse, points (max=5)

To assess the nature of the identified trends, we conducted a statistical analysis of the significance of the differences using the Student's T-test. The comparison results are presented in Table. 2.

Table 2. T-test for Independent Samples 2021 / 2023 years for University of Tyumen and University of Ruse

		Mean for Group 2021	Mean for Group 2023	T-value	df	P
University of Tyumen	I would like to have my own business	3,93	3,98	-0,49	488	0,62
	I prefer to work in a large company	3,36	3,66	-2,89	488	**0,004**
	I would like to have a family business with my relatives	2,70	2,31	3,44	488	**0,0006**
"Angel Kanchev" University of Ruse	I would like to have my own business	3,35	3,34	0,15	868	0,88
	I prefer to work in a large company	4,13	4,04	1,10	868	0,27
	I would like to have a family business with my relatives	3,15	3,05	1,06	868	0,29

From Table. 2 we can see that for the University of Ruse the statistical differences are not significant. The preference for career trajectories is stable: the most popular is building independent business, while a family business is less desirable.

For students from University of Tyumen, the popularity of starting their own business has not changed over time - this is the most desirable career path. This empirical result can confirm the effectiveness of government programs to promote youth entrepreneurship.

At the same time, statistically significant differences were found in the career preferences of Russian students:

- the increase in the popularity of working in a large company is statistically significant ($p = 0.004$);

- a significant decrease is shown in the career orientation "opening a family business" ($p= 0.0006$).

From our point of view, the first result can be explained by the fact that there is an increase in industrial production in the Russian Federation, despite the complexity of the foreign policy situation. In 2023 The growth of the Russian economy was the highest over the last decade and amounted to 3.6% (TASS, 2024). The economic boom is leading to students' desire to work for large public and private companies.

At the same time, the negative trend in the popularity of family business as a possible career after graduation is alarming. From the data obtained, we can conclude that the program carried out by the Chamber of Commerce and Industry to popularize family business does not have a positive impact on the attitudes of students. The lack of educational programs on family business in Russian universities (including Tyumen State University) and the negative image of this type of entrepreneurship in the film industry lead to the fact that this form of employment is not interesting for young people.

Since family business is the basis of small and medium-sized enterprises, the decline in popularity of this form of employment among young people will create a risk of insufficient continuity between generations. This can put family businesses at risk of survival due to staffing shortages. In general, creating a negative image of family entrepreneurship distorts the traditional values of the family, focusing on the dominance of selfish aspirations even among family and friends. While the family has historically been a form of collective labor activity and a place of emotional and psychological relief.

Thus, our research allowed us to confirm the hypothesis that family business in the Russian Federation as a form of future employment for young people is less attractive compared to independent business. We see the reason for this unpopularity in the ineffective policies to promote and develop this form of entrepreneurship: the media very rarely touch on this topic; there are no educational programs in the higher education system aimed at training successors; The film industry creates a negative image of family-owned companies.

4. CONCLUSION

In the context of foreign economic and political struggle, diversification of the economy is possible through small and medium-sized businesses, the bulk of which are represented by family companies. Flexibility, adaptability, and high stress resistance of family companies can become a driver for the development of the national economy.

The national project "Small and Medium Enterprises" launched in 2018 in the Russian Federation is aimed at the development of all forms of business. As our theoretical research has shown, youth entrepreneurship is developing much more intensively than family entrepreneurship. The flagship of this development is the Federal project "Platform of University Technological Entrepreneurship". Family entrepreneurship is supported and developed thanks to the efforts of the Chamber of Commerce and Industry of the Russian Federation.

The purpose of the presented work was to study the dynamics of career preferences of students from Russia and Bulgaria (the comparison was made in 2021 and 2023). The results of the study allow us to assess the extent to which family business is an attractive model of future employment for young people.

This empirical study was conducted within the framework of the InterGen project aimed at revealing the characteristics of family entrepreneurship in different countries and examining students' attitude to building a joint business with relatives.

The results of the statistical analysis showed that the most desirable thing for students in the two countries is to build their own business. The second most popular is working in a large company. The least attractive is the prospect of creating or continuing a family business. Comparison by year showed that for the University of Ruse the statistical differences are not significant. For University of Tyumen students, the popularity of owning their own business has not changed over the years; this form of employment remains the most desirable career path. At the same time, the career orientation "opening a family business" shows a significant decrease. This empirical result may indicate the ineffectiveness of government programs to popularize family businesses.

We believe that in order to increase the involvement of young people in family business, it is necessary to organize a targeted policy to popularize this type of economic activity. As possible measures, we propose: 1) promoting positive examples of family businesses through the media (newspapers, magazines, television, radio); 2) organization of trainings, seminars, lectures on family entrepreneurship in public open areas of the city for university students and all visitors; 3) inclusion of academic disciplines on family business in undergraduate and graduate programs at universities in the Russian Federation and Bulgaria.

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SUSTAINABILITY AND RESILIENCE FROM THE PERSPECTIVE OF THE LABOUR MARKET OF CENTRAL AND EAST EUROPEAN (CEE) MEMBER STATES

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Abstract: The paper examines the short-term relationship among the labour market and two key indices, namely the ESGI (Environment, Social, and Governmental Index) measuring sustainability-related risks, and the SRI (State Resilience Index), focusing on Central and Eastern European (CEE) member countries. The findings indicate that an expansion of the labour force contributes to heightened environmental, social, and governance risks, but enhances state resilience. Factors such as adapting to digitisation, enhancing quality of life amidst economic growth, and increased education levels contribute to a more robust workforce. Economic growth tends to discourage individuals from pursuing higher education, and unemployment among those with tertiary education disrupts the labour market equilibrium. In this context, state intervention through additional investments in education yields positive effects on the labour market and, by extension, on state resilience, potentially mitigating environmental, social, and governance risks. The results address existing gaps in the literature and provide valuable insights for shaping economic policy measures in CEE countries.

Keywords: sustainability, resilience, labour market, digitisation, economic growth.

1. INTRODUCTION

Reducing environmental, social, and governance risks and strengthening state resilience are macroeconomic policy objectives which are receiving increasing attention due to their importance in supporting development.

ESGI values are considered a sustainability assessment tool (Rajesh, 2019). Sustainability involves meeting the needs of the present without affecting the ability of future generations to meet their own. Performance in terms of sustainability involves analysing the potential negative impact of economic activities on the environment in both developed and emerging countries. Organizational sustainability takes shape at the intersection between the environment and society (Rajesh, 2019). In the initial stages, practices oriented towards ESG directions are considered costly. When they exceed the minimum requirements of legal

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standards, they lead to a reduction in the value of companies and have unfavourable macroeconomic effects (Sadiq et al., 2020). Adopting environmentally and socially responsible measures through good governance is necessary; otherwise, the long-term costs can be much higher.

The concept of ESG existed before the 1950s, but only in the 2010s did it start to be included among the points of interest for companies (Gao et al., 2021). The three directions of the concept, according to Gao et al. (2021), refer to social responsibility (improving environmental performance in production and reducing environmental costs per output unit), social responsibility (presupposes that companies apply business ethics, social ethics, legal standards to which is added the importance of relations with the external society, which includes human rights, the interest of different parties, and ecological improvement), and corporate governance responsibility (the management system through which a company should improve its modern corporate system). ESG is a leading indicator of non-financial performance. Baier et al. (2020) consider the concept of ESG as not clearly defined and therefore difficult to measure. On the same line is the argumentation of Dmuchowski et al. (2023), who found that ESG performance analyses are not conclusive due to the lack of a clear definition, available data, insufficient quality of ESG data and ratings.

Resilience is considered the result of the application of structural economic policy measures generating sustainable economic growth. Such growth gives the economy the capacity to cope with shocks, to overcome them easily, and to reduce risks (Webber et al., 2018). All the ways in which a country achieves its economic growth goals support resilience. According to Muštra et al. (2017), growth is associated with resilience, and this generates opportunities in the labour market. Associating resilience with economic policy brings to the fore the state and its ability to be resilient as a result of measures able to have a positive impact on the economy, society, and the environment.

The concept of resilience, borrowed from other disciplines, essentially from psychology and ecology, refers to the ability to recover from shocks and cope with future shocks (Gong et al., 2020). According to Gong et al. (2020), the concept of resilience is site-sensitive, multi-layered, and multi-scalar, conflict-ridden, and contingent. Resilience depends, to a large extent, on the nature of the crises, on institutional experience in managing them, on the economic policy measures taken, and on the regional industrial structures which can influence the recovery rates. The increase in the number of events with a high degree of uncertainty, such as natural, social, political, and economic risks, has brought to the fore the need for resilience.

Resilience is associated with the labour market. A resilient labour market offers conditions for the workforce to overcome difficult situations and the possibility of designing and implementing actions through which working conditions will be modified favourably (Ryelzic & Anitha, 2019). The resilient labour market is characterized by an upward demand for labour, the capacity to absorb as much of the labour force as possible, and adaptation to changes (Malik & Garg, 2017). Periods of crisis, usually unbalancing, are easier to overcome in conditions of resilience, and in the labour market, such a situation benefits the educated workforce (Kasen, 2018). More recently, digitization is producing transformations in the labour market with effects on resilience. The process of accelerated digitization produces increased productivity, connectivity, and transformations of workforce skills (Androniceanu et al., 2020).

The importance of sustainability and resilience justifies the proposed research objective, namely to examine the short-term relationship among the labour market and two key indices, namely the ESGI (Environment, Social, and Governmental Index) measuring sustainability-related risks, and the SRI (State Resilience Index), focusing on Central and Eastern European (CEE) member countries.

2. LITERATURE REVIEW

2.1. ESGI (Environment, Social and Governance Index)

The effects of ESGI, especially at the microeconomic level, have been intensively studied in the literature. Sadiq et al. (2020) demonstrated, using the example of Malaysian companies from 2011 to 2019, that reduced ESG risks increase the value of companies; however, an excessively high focus on ESG directions has opposite effects. The results of the best ESG-performing companies are based on investments, according to Umar et al. (2020). The authors concluded that there is a risk of contagion and diminishing benefits during turbulent economic and social periods. Duque-Grisales and Aguilera-Caracuel (2021), seeking to determine the extent to which a firm's financial performance is associated with reduced ESG risks in the markets of 104 multinational companies in Brazil, Chile, Colombia, Mexico, and Peru between 2011 and 2015, noted that the relationship is negative. Evidence was also provided regarding the moderating effect of financial relaxation and international geographic diversification on the relationship between financial performance and reduced ESG risks.

Cek and Eyupoglu (2020) assessed the influence of ESG performance on the economic performance of 500 companies for the period 2010-2015 and found a significant relationship between them. The significance of the relationship is observed between social and governance performance and economic performance, but not between environmental and economic performance.

The relationships between ESG and financial performance of companies originating from emerging and developed countries were assessed by Garcia and Orsato (2020). This relationship is affected by existing institutional weaknesses in emerging countries, the tendency of firms to prioritize capital accumulation, and the lack of recognition of the strategic benefits of socially responsible investment. Mohammad and Wasiuzzaman (2021) studied the ESG effects of 661 firms in Malaysia between 2012 and 2017 on their performance, moderated by the firm's competitive advantage. Reduced risks associated with ESG components improve firm performance and are associated with highly competitive advantage.

Zheng et al. (2022) conducted research in which they investigated the bidirectional cointegration relationship between ESG performance and corporate green innovation on a panel of 770 Chinese firms from 2011 to 2020. It was found that there is a long-term bidirectional correlation between ESG performance and ecological innovation of companies. ESG performance co-evolves with green innovation production for the profile industry, and ESG performance is found in a long-term relationship with green invention patent production for the polluting industry.

The impact of ESG on public and private companies globally during the period 2007 – 2015 was studied by Li and Wu (2020). They found a robust and striking difference between public and private firms. Private companies manage to reduce the risks associated with ESG compared to public ones. At the root of these discrepancies are conflicts of interest among shareholders, but the conflict is mediated by the type of ownership, proximity to end consumers, and the type of ESG incidence.

ESG performance maximizes financial performance in the case of companies that pay attention to shareholders, especially external ones. Maximizing shareholder value is considered an optimal strategy for achieving the company's objectives, to which efforts to improve non-financial performance are added, according to Al Amosh et al. (2022).

Dmuchowski et al. (2023) found that most studies capture a positive correlation between ESG factors and financial performance, with this positive relationship being more pronounced in the long run. The conclusion is drawn from an analysis of the specific case of Poland. The

main obstacles to sustainable financial development were identified as educational and communication barriers, with education standing out as a prerequisite for the ability to achieve financial development goals.

The effects of ESGI have also been studied at the macroeconomic level, but to a small extent. Sadiq et al. (2022) analysed the impact of ESG and economic growth on the objectives of sustainable development in ASEAN countries for the period 1986–2020. Low risks associated with ESG and economic growth are positively associated with the sustainable development of Asian states.

Most of the existing studies focus on analysing the relationship among various variants of ESG and the financial performance of firms. Despite not providing unidirectional results, these studies highlight the positive relationship between reduced ESG risks and maximizing firm performance. Given the limited study of the relationship between ESGI and the labour market, with macroeconomic analyses being almost neglected, we identify a deficit in the literature that we aim to address by validating the research hypothesis (H1): *the labour market influences the risks associated with ESG*.

2.2. SRI (State Resilience Index) and resilience of labour market

Giannakis and Bruggeman (2019) compared the economic resilience of rural and urban EU regions and its determinants using three different resilience indicators based on changes in employment. The conclusion is that migration and agriculture have significantly positive effects on rural-urban economic resilience.

One of the most evident effects of an economic crisis is felt in the labour market through an increase in the unemployment rate. Liotti (2020), after studying 20 Italian regions between 2001 and 2016, found that the most vulnerable group in crisis conditions on the labour market is that of young people. Empirical results do not demonstrate that high labour market flexibility reduces youth unemployment. High resilience, translated into mitigating the impact of a recession on both youth and adult unemployment, is supported by regional exports, participation in regional politics, average wage growth, private investment, and regional productivity.

Bai et al. (2021) constructed an index of resilience for US firms in the context of the Covid-19 pandemic by assessing the feasibility of working from home and labour demand. Digitization has been found to make certain activities, jobs, and companies resilient to unforeseen shocks. Firms with high digital resilience have shown good overall performance, especially in non-core industries. The ability to use digitization for remote work matters more in non-high-tech industries than in high-tech ones, and bridging the digital gap is possible with the help of significant investments in software. Androniceanu et al. (2020) demonstrated the influence that digitization had on the workforce in 19 developed countries in a certain period, producing structural changes as it alters economic and social patterns.

Grigoli et al. (2020) demonstrated the effects of technological progress, especially on productivity and economic growth, and the fact that it reshapes the labour market. Automation has significant negative effects on the labour market participation rates of middle-aged men and women, and there is a high likelihood that routine workers will face challenges. However, increasing spending on active labour market programs and education is associated with lower negative effects of technological change on labour market participation.

Jollès et al. (2023) assessed the structural characteristics important for economic resilience, especially those likely to absorb shocks in EU states. Based on data characteristic of the period 1998-2018, it was found that the factors that allow the absorption of shocks differ from those which facilitate recovery in the face of a common shock. Labour market

characteristics play an important role in absorbing shocks, and labour market rigidity dampens resilience the most, especially factors that hinder labour reallocation and the production of goods and services. High public debt hinders the capacity to absorb shocks, high private debt weakens the capacity for resilience, while a high degree of economic openness has a negative impact on the absorption capacity in the event of a common shock because it also affects trading partners but has a positive impact on resilience. Furthermore, resilience capacity differs among countries and depends on well-calibrated reforms.

The literature demonstrates concern for resilience in relation to the labour market, economic growth, and digitalization. However, the subject remains open to analysis, especially in correlation with ESGI and SRI, where the gap in the literature is evident through the gaps in the analysis of state resilience. In this context, we aim to address the existing deficit by validating the research hypothesis (H2): *the labour market, economic growth, and digitization influence the resilience of the state*.

The two hypotheses enable the achievement of the proposed objective, which is to examine the short-term relationship among the labour market and two key indices, namely the ESGI (Environment, Social, and Governmental Index) measuring sustainability-related risks, and the SRI (State Resilience Index), focusing on Central and Eastern European (CEE) member countries.

3. METHODOLOGY

3.1. Data

Data describing the dependent variables are very limited in availability. Therefore, the short-term empirical analysis, confined to the year 2022, can offer significant information, making a valuable contribution to the literature and economic practice. It also sets the stage for future research, where directions or trends worthy of further exploration will be identified. The group of countries analysed comprises Central and Eastern European EU members (Estonia, Latvia, Lithuania, Poland, Czech Republic, Slovakia, Hungary, Romania, Bulgaria, Slovenia, and Croatia).

The dependent variables of the analysis describe risks associated with sustainability (ESGI) and state resilience (SRI). The ESGI (Environmental, Social, and Governance Index) covers major aspects related to environmental risks (30%), human rights (50%), health and safety (20%). ESGI sub-indices cover the environment (environmental pollution and climate change), human rights (social rights, civil and political rights, collective rights indicators), health and safety (life expectancy, access to drinking water, safety at work, social protection). According to the Global Risk Profile (www.risk-indexes.com), the ESGI assessment also takes into account spatial inequity adjustment (rural/urban). ESGI is an index that describes environmental, social, and governance risks, taking values between 0 and 100. The higher the value of the index, the higher the risks.

SRI (State Resilience Index) measures seven pillars of resilience: inclusion (of young people, politics, access to financial sources, group-based inclusion, access to economic resources, access to employment, protection against precarity), social cohesion (social capital, social relationships, confidence in national institutions), state capacity (finances, government effectiveness, disaster risk reduction, public health, education outcomes, rule of law, freedom from corruption), individual capacities (food/nutrition, the education system, health, wealth), environment/ecology (pollution, ocean and fisheries health, agricultural productivity, ecosystem wealth, biodiversity, long-term climate stability, clean energy, water availability), economy (diversification, business environment, dynamism/innovation, physical infrastructure,

capital flows, economic management), civic space (engagement, accountability, democratic structures, human rights and civil liberties, information access) (Anastopoulo, 2022).

The independent variables assess the labour market and other related macroeconomic aspects: labour force (LAB), enrollment in secondary school (ESS), enrollment in tertiary school (ETS), government expenditure for education (GEE), unemployment (UNE), unemployment with advanced education (UNEA), population (POP), individuals using the internet (IUI), and gross domestic product (GDP). Among the nine variables, we consider six of them relevant to describe the labour market (LAB, ESS, ETS, GEE, UNE, UNEA) because they provide information regarding its situation and education, a factor with a direct and decisive impact, and three of them as control variables. Where the statistical information was not valid for the year 2022, we considered the values constant from the previous year. For the accuracy of the results, the data were logarithmized.

3.2. Methodology

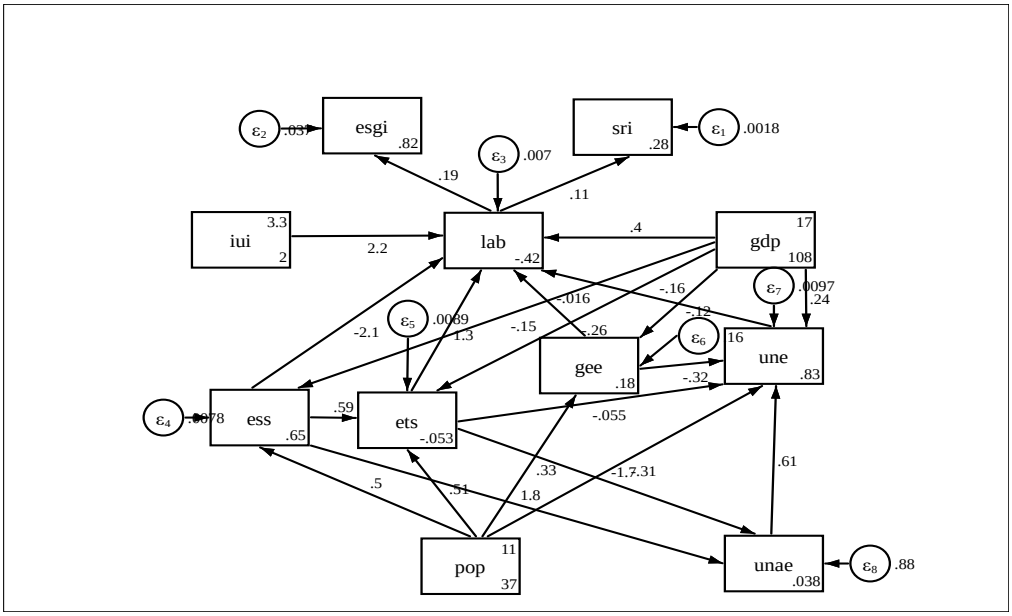
The structural equations method was applied. This method involves running linear regressions presented as path diagrams showing the direct relationships among variables combined with a factor analysis. The structural equation method offers the advantage of estimating multiple and interdependent dependencies in a single analysis. The structural model presents the potential for causal dependence between endogenous and exogenous variables. The relationships among variables take the form of regression equations:

$$Y = \alpha + \beta 1X1 + \ldots + \beta nXn \quad (1)$$

where Y is dependent variable, α is constant (intercept), β1,…,n are regression coefficients, and X1,…,n are independent variables.

4. RESULTS AND DISCUSSION

The empirical results are presented in Graph 1 and Table 1. Equation (1) is reformulated in forms (2 - 7).



Graph 1: Structural model (Author`s contribution)

$$SRI = 0.28 + 0.11 \times LAB \quad (2)$$
$$ESGI = 0.82 + 0.19 \times LAB \quad (3)$$
$$LAB = -2.08 \times ESS + 1.34 \times ETS + 0.4 \times GDP + 2.17 \times IUI \quad (4)$$
$$ESS = 0.65 + 0.49 \times POP \quad (5)$$
$$ETS = 0.51 \times POP - 0.26 \times GDP \quad (6)$$
$$UNE = 0.83 + 0.61 \times UNAE - 0.32 \times GEE \quad (7)$$

From equations (2-7), Graph 1, and Table 1, it can be observed that the sustainability and resilience of the countries in CEE are influenced by the labour market situation. An increase in the size of the labour force generates an increase of 0.11 units in SRI and 0.19 in ESGI. In other words, the rising LAB accentuates ESG risks but contributes to strengthening SRI. If LAB effects are disregarded, the trend would be similar. ESG risks would increase (α = 0.82), and SRI would improve (α = 0.28).

Table 1. Structural model results (Author`s contribution)

Variable	Coefficient	z	P>/z/	[95% Coefficient Interval]	
SRI					
LAB	0.11	47.35	0.000	0.01	0.11
_cons	0.28	10.87	0.000	0.23	0.34
ESGI					
LAB	0.19	18.59	0.000	0.16	0.21
_cons	0.82	6.99	0.000	0.59	1.05
LAB					
ESS	-2.08	-3.36	0.001	-3.29	-0.87
ETS	1.34	0.39	0.001	0.57	2.10
UNE	-0.16	-1.04	0.298	-0.46	0.14
GEE	-0.02	-0.12	0.903	-0.27	0.24
GDP	0.4	3.55	0.000	0.18	0.62
IUI	2.17	1.98	0.048	0.02	4.32
_cons	-0.42	0.87	0.624	-2.12	1.27
ESS					
POP	0.49	2.61	0.009	0.12	0.87
GDP	-0.15	-1.36	0.175	-0.37	0.07
_cons	0.65	3.83	0.000	0.32	0.98
ETS					
ESS	0.59	1.83	0.067	-0.04	1.22
POP	0.51	1.98	0.047	0.01	1.02
GDP	-0.26	-2.02	0.043	-0.51	-0.01
_cons	-0.05	-0.19	0.850	-0.6	0.49
UNAE					
ESS	1.76	0.78	0.436	-2.67	6.18
ETS	-1.7	-0.66	0.507	-6.71	3.31
_cons	0.04	0.05	0.959	-1.42	1.49
UNE					
ETS	-0.06	-0.13	0.900	-0.91	0.80
UNAE	0.61	12.95	0.000	0.51	0.69
GEE	-0.32	-2.18	0.030	-0.61	-0.03
POP	-0.31	-0.84	0.399	-1.02	0.41
GDP	0.24	1.31	0.189	-0.12	0.59
_cons	0.83	3.26	0.001	0.33	1.33
GEE					
POP	0.33	0.38	0.707	-1.37	2.02
GDP	-0.12	-0.24	0.811	-1.12	0.88
_cons	0.18	0.23	0.821	-1.34	1.69

The size of LAB changes under the influence of ESS AND ETS, GDP, and IUI. Increasing ESS contracts LAB (β_{ESS} = -2.08), and increasing ETS has the opposite effect (β_{ETS} = 1.34). As ESS increases, the labour force in the CEE market decreases to a greater extent than the increase due to ETS. The explanations are found in the current trends imposed by the changes induced by digitization and technology (Haller, 2023). GDP and adaptation to digitization support labour (β_{GDP} = 0.4 and β_{IUI} = 2.17).

ESS is increasing (α = 0.65). Development efforts and emphasis on studies are visible through the trend of educational progress. In addition to the fact that education is supported by state policy, given the advantages it generates in society, the economy, and beyond, people are becoming aware that knowledge adds value and increases their chances of finding a job and improving their quality of life. The increase in POP is positively reflected in the tendency to continue basic studies (β_{POP} = 0.49).

If we notice from equation (5) that, regardless of demographic evolution, the tendency is to increase ESS, this is not true for ETS. ESS depends on the positive evolution of POP (β_{POP} = 0.51) in the sense that demographic progress is accompanied by educational progress. However, from equation (6), it appears that GDP is negatively associated with the decision to pursue higher education (β_{GDP} = -0.26). Sustained economic growth improves the quality of life in such a way that it was found to be associated with the tendency to reduce the number of those who decide to continue their studies with the tertiary education cycle.

Labour force refers to people who are able to work, employed, and looking for work. Unemployment, in turn, if we abstract from influencing factors, is increasing in CEE countries (α = 0.83). UNAE influences UNE in CEE countries (β_{UNAE} = 0.61). Instead, the involvement of the state by increasing GEE has a positive effect on the labour market, contributing to the reduction of UNE (β_{GEE} = -0.32).

ESG and SRI risks are subject to the influence of other variables from those analysed; however, their effect has no statistical significance, which makes their interpretation difficult (Table 1). Increasing UNE and increasing GEE could cause a decline in LAB (β_{UNE} = -0.16; β_{GEE} = -0.02). If we disregard the analysed variables, the labour force could be reduced in the markets of the CEE countries (α = -0.42). The number of ESS can be reduced as a result of an increase in GDP (β_{GDP} = -0.15), and that of people who decide to continue higher education can be positively influenced by the number of secondary school graduates (β_{ESS} = 0.59). Additionally, if we remove from the discussion the influence of the analysed variables, in the CEE countries, the tendency to compress the number of ETS can be manifested (α = -0.05). UNAE can be influenced both by ESS, in a negative sense (the higher the ESS, the higher the probability of an increase in UNE for ETS (β_{ESS} = 1.76)), and by ETS in a positive sense (the higher the ETS, the higher the probability of UNE reduction is higher (β_{ETS} = -1.7)). UNE among ETS is likely to be influenced by ESS and ETS. If we abstract from educational factors, there is a probability of increasing UNE among ETS (α = 0.04). If we refer to UNE, in CEE countries, there is the possibility that it will decrease as a result of the increase in ETS (β_{ETS} = -0.06), POP (β_{POP} = -0.31) but increase as a result of GDP (β_{GDP} = 0.24). Education is an important factor in progress, which is why the involvement of the state through investments is a constant objective of economic policy. The results show the probability that GEE will increase even in the absence of the action of the analysed factors (α = 0.18). POP growth can print the same trend (β_{POP} = 0.33), while GDP can reduce GEE (β_{GDP} = -0.12).

There is a good fit between the model and the data according to the SRMR (Standardized Root Mean Squared Residual) value of 0.046. The good fit of the model equations reveals the high influence of the determinants of LAB on ESG risks and SRI (Table 2). The influence of these factors amounts to a weight of 99.99%. LAB imprints ESG risks in the proportion of 96.92% and SRI in the proportion of 99.51%. These weights show how

important LAB is for macroeconomic stability. The determining factors of LAB, more specifically ESS, ETS, UNE, GEE, GDP, and IUI have an influence of 99.97%. Demographic growth has an impact on the ESS of 99.63%, and together these two factors determine the weighted ETS of 99.47%. As a result of the statistical insignificance of the results, UNE among those with higher education is affected by the determining factors in the weight of only 17.32%. In the cases of UNE and GEE, the determinants have an impact of 98.48% and 76.66%, respectively.

Table 2. Equation – level goodness of fit

Variable	R^2	Variable	R^2	Variable	R^2	Variable	R^2
LAB	0.9997	ESGI	0.9692	ETS	0.9947	UNE	0.9848
SRI	0.9951	ESS	0.9963	UNAE	0.1732	GEE	0.7666
Overall	0.9999						

LAB exerts direct effects on ESG risks and SRI. Some factors with influence on LAB, in this case, ESS and ETS, GDP, and IUI, also have direct effects on it. Similarly, POP makes its mark directly on ESS and ETS. ETS also depends directly on GDP. UNE among ETS and GEE exerts, in turn, direct influence on UNE. We find indirect influences (from ESS, ETS, and IUI to SRI and ESGI) and total (from LAB to ESGI and SRI, from ESS, ETS, and IUI to LAB, ESGI, and SRI, from POP to ESS, on the one hand, and from POP and GDP to ETS, from UNAE and GEE to UNE). The results of the empirical analysis validate the two research hypotheses and enable the achievement of the proposed objective.

5. CONCLUSION

The paper examines the short-term relationship among the labour market and two key indices, namely the ESGI (Environment, Social, and Governmental Index) measuring sustainability-related risks, and the SRI (State Resilience Index), focusing on Central and Eastern European (CEE) member countries. To achieve this objective, we started with two research hypotheses: (H1) the labour market influences the risks associated with ESG, and (H2) the labour market, economic growth, and digitization influence SRI.

The conclusions follow several directions corresponding to the equations of the structural model. The growth of the labour force in the market of CEE countries accentuates environmental, social, and governance risks but supports the resilience of the state. Adaptation to digitization and familiarity with technology, improved quality of life amid economic growth, and advancement in knowledge through higher education are fueling the workforce of CEE countries. The number of those who decide to pursue secondary and higher education increases with demographic growth, and the number of those who pursue higher education decreases in conditions of economic growth. If unemployment among those with higher education negatively affects the labour market, the involvement of the state by allocating funds to education affects it positively. Therefore, the labour market of the CEE countries, as a result of the increase in the labour force, accentuates environmental, social, and governance risks and, simultaneously, supports the resilience of the state.

The results confirm those of Bai et al. (2021), Androniceanu et al. (2020), Grigoli et al. (2020), and indirectly those of Dmuchowski et al. (2023). The analysis has limitations, with the main one stemming from the lack of data availability over a long period of time. The results contribute to the literature, provide support for economic policymakers, and open the way for future investigations of the subject.

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POST-HOC ANALYSIS OF DIGITAL DEVELOPMENT IN PLS-SEM

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Abstract: This study attempts to determine and visually present the effect of educational, economic, energy-related, and ecological latent variables and adequate manifest variables on digital development in 33 European nations from 2010 to 2016. The results are presented using the partial least squares structural equation modeling (PLS-SEM) methodology to evaluate the model's fit. Afterwards, the importance-performance map analysis (IPMA) was generated in order to perform post-hoc analysis. The IPMA indicates that the social latent variable has positive effects on digital development, as demonstrated by a performance score over 50. The effects of the energetic latent variable on digitalization reflect the lowest performance and the lowest positive effects. Therefore, the findings recommend an extensive examination of the interaction between energy-related factors and the diffusion of environmentally responsible digital progress. In reverse, the ecological latent variable has an adverse effect on digital development, as any drop in air pollution emissions is related to digital development.

Keywords: digital development, sustainability, PLS-SEM, IPMA.

1. INTRODUCTION

A widespread and complex phenomenon in modern society, such as the digital development process, is subject to the effects of multiple external dimensions. This primarily applies to the influence of educational advancement as the foundational structure for attaining knowledge and competencies necessary for digital progress, a subject that has been extensively examined by multiple scholars (Marhraoui, 2023; Yuan et al., 2023). Furthermore, the effects extend to economic expansion and progress, serving as monetary incentives for the advancement of digital technology and its application across sectors (Ze et al., 2023). In addition, numerous studies have validated the critical importance of energy sector management, which ensures energy stability—a fundamental requirement for the advancement and implementation of digital

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technology—by promoting rational energy resource consumption (Ren et al., 2021). Due to the essential necessity of satisfying the energy demands of digital developments, this must be accomplished in an environmentally sustainable manner by minimizing the release of hazardous gases into the atmosphere (Li et al., 2021). For that, diverse approaches to addressing the environmental challenges of the digital age have been proposed in the literature. These include expanding the economies of scale of tertiary industry operations, promoting the development of environmentally friendly technologies, and reducing dependence on coal-based energy sources (Wang et al., 2022).

The implementation and growth of digital technology are critical for both business and social endeavors, as they are acknowledged to be effective methods for attaining holistic advancements in the future (Yuan et al., 2021). Future scientific research should not ignore the multidimensional foundation of digital development. As a result, the primary objective of this research can be summarized as performing a visual assessment of digitalization in the scope of educational, economic, energy and ecological dimensions. For that purpose, the PLS-SEM methodology and its visual tool, IPMA, have been implemented. The primary driver for investigating multidimensional effects on digitalization's development is a shortage of post hoc analyses, which are useful supplementary mechanisms when examining such highly complex phenomena. This ultimately contributes to a crucial scientific contribution related to discovering those dimensions that have a substantial impact on the progression of digitalization; however, their performance yields less impressive outcomes. The aforementioned dimensions present major opportunities for decision-makers in regards to the future strategy and management of digital progress.

The study is segmented into six parts. The subsequent segment offers contextual details regarding the theoretical underpinnings of digitalization dimensions. Section 3 presents a brief summary of the data and the PLS-SEM methodology utilized in the research. Section 4 presents crucial empirical data on the educational, economic, energetic, and ecological impacts of digitalization. The fifth and sixth sections of the paper offer a thorough analysis of the primary discoveries, in addition to outlining the constraints of the research and outlining forthcoming research objectives.

2. LITERATURE REVIEW

The previous theoretical discussion provides proof that the process of digitalization is difficult and that its effects can be noticed across all areas of society and economic activity. The fast development of digital technology is influenced by various factors. This research utilizes many indicators of ICT growth, along with an ICT development index calculated by the International Telecommunication Union (ITU), to quantify the level of digital progress. The proxies employed in this analysis consist of the number of active mobile-broadband subscribers per 100 inhabitants, the number of fixed broadband subscriptions per 100 inhabitants, and the number of secure Internet servers per million people.

Educational dimension. The knowledge society places education at the forefront of all development and necessitates a flexible education system that can adapt to the challenges of the digital era. According to Vajen et al. (2023), the promotion of digital technology adoption by the education system and teachers is dependent upon the level of their digital skills. A recent literature review on digital competencies conducted by Zhao et al. (2021) found that university students and

professors possess a fundamental level of digital competencies and highlighted the essential role of educational institutions in enhancing the digital skills of these categories. According to Iordache et al. (2017), professors and teachers need to teach digital literacy through educational institutions in order to cultivate a digitally proficient populace that can create a digital society. Moreover, the labor market has not been immune to the changes in the digital environment. According to Alper and Alper (2020), the education system needs to adapt to the labor requirements of the digital age by prequalifying low-skilled workers. Holford (2020) has also identified an urgent need to align the competencies currently available in the labor market with those that are in demand. According to Van Laar et al. (2017), the responsibility lies with individuals to integrate their educational skills with the desired digital skills of the 21st century in order to effectively adjust to the demands of the digital age. In line with previous literature, the selected indicators that represent the educational dimension are: advanced education population, labor force and working-age population rate with advanced education.

Economic dimension. According to Fernández-Portillo et al. (2020), the integration of digital technology in industry reveals a direct correlation between ICT advancements and economic growth. The exact relationship between GDP growth and digital development cannot be measured due to external threats related to the ICT industry, such as intangible benefits from technology use. Watanabe et al. (2016) reported that a prevalent issue in the field of ICT is unaccounted GDP. The emergence of a challenge has been observed as a consequence of utilizing the Internet, which renders technology accessible to individuals for replication without due compensation (Watanabe et al., 2016). On the other side, Ze et al. (2023) recognize the importance of governmental entities in directing a substantial portion of investments towards promoting financial aid for the ongoing advancement of technology. According to a recent study, authors Koutroumpis et al. (2020) discuss that R&D incentives achieve greater effectiveness on revenue in the ICT sector. They propose a tax relief R&D policy with the purpose of increasing the amount of R&D investments. A study conducted by Lee et al. (2022) confirms that the government should allocate research and development investments towards the rising ICT sector that targets emerging ICT firms. Thus, indicators used to represent economic dimension in this study are: GDP per capita and per worker, along with R&D expenditure.

Energetic dimension. According to Chien et al. (2021), the advancement of digital technology can contribute to the expansion of the economy, which in turn may lead to a rise in energy consumption. The progression of digitalization can be identified by the quantity of ICT artifacts that are employed within both the societal and industrial domains. The growing number of digital devices will culminate in an equivalent rise in the demand for electrical energy to sustain their operation (Koot & Wijnhoven, 2021). Hosan et al. (2022) argue that the integration of digital appliances in smart homes and the service industry might result in a boost in energy usage. However, some studies suggest that over an extended period, digitalization has the capacity to decrease energy usage through the encouragement of technological investments, the cultivation of human capital as the intellectual foundation for the development of energy-efficient technology, and the integration of digitalization into industrial processes that optimize energy demand structure (Xu et al., 2022). According to the presented literature, the indicators employed in this study to represent the energetic dimension are: electricity generation from coal, oil, other renewables, solar and wind.

Ecological dimension. Cutting-edge digital technology with energy-saving characteristics continues to shape energy consumption in the digital age. Digital technology represents an energy-

efficient alternative to address the intensified energy demands associated with industrial activities (Feng et al., 2022). According to Zhang et al. (2022a), the use of digital technology leads to increased energy demand through powering its production, operation, and maintenance. However, the integration of energy efficiency principles into digital technology is anticipated to result in a reduction in energy consumption and, consequently, in carbon emissions. The study by Ulucak et al. (2020) examined the carbon dioxide emissions linked to the digital development in emerging economies and the results of the research study suggest that the digital development is related with a decreasing amount of CO_2 emissions. Recent research suggests that the diffusion of digital devices that have integrated the latest energy and ecological characteristics can have a positive impact on environmental preservation (Ma et al., 2022). Therefore, adopted indicators in this study that represent the ecological dimension are: GHG emissions and CO_2 emissions per capita.

3. DATA AND METHODOLOGY

For an evaluation of the implications of education, economy, energy, and ecology on digital progress, the research study examined annual information from 27 European Union members and selected countries outside the EU, including the United Kingdom, Iceland, Norway, North Macedonia, Serbia, and Turkey. The figures were accumulated over an interval of six consecutive years, starting in 2010. With the goal of investigating the effects of specific dimensions on digital development, the SmartPLS 4 program was applied. This software supports the application of the graphic tool IPMA.

Partial Least Squares Structural Equation Modeling (PLS-SEM) was introduced by Herman Wold in 1975 as an approach that entails a combination of ordinary least squares (OLS) and principal component analysis (PCA) techniques to derive path coefficients that enhance the explained variance and minimize construct error (Hair et al., 2017). The method is commonly used in research studies with non-normal data, small sample sizes, and when focusing on prediction (Hair et al., 2012). It is a preferred methodology over others when dealing with complex models that incorporate a large number of constructs, variables, and structural paths with varying data distributions (Dadhich et al., 2022). According to Munerah et al. (2021), PLS-SEM has been identified as a valuable tool for conducting exploratory research and prediction studies. When establishing the minimum sample size, it is necessary to consider various factors, such as the desired level of statistical power, the effect size, and the level of significance. According to Hair et al. (2017), the "ten times rule of thumb" is employed, whereby the sample size is required to be ten times greater than the maximum number of items present in any given construct. The latest research from Ringle et al. (2023) on PLS-SEM application in data studies summarizes commonly used thresholds for metrics in evaluating measurement PLS-SEM models by conducting reliability and discriminant validity tests, followed by structural PLS-SEM model evaluation through path coefficients and their statistical importance. In the scope of PLS, a visual tool for post-hoc analysis named importance performance map analysis (IPMA) is used. IPMA's objective is to investigate the importance (total effects) and performance of the latent variables and manifest variables that are employed to explain the research problem (Teeluckdharry et al., 2022). Therefore, IPMA provides deeper knowledge about PLS-SEM empirical results (Ringle & Sarstedt, 2016). The approach identifies variables, both latent and manifest, that have a significant impact on the research problem, which is the target variable. However, if it acknowledges that these variables

have low performance, it focuses on them as an opportunity to enhance the outcomes of the target variable (Hauff et al., 2024).

4. RESULTS

Developing a PLS-SEM model involves a check of the reliability of variables and the discriminant validity of the measurement model. This study involved the mathematical estimation of factor loadings for the manifest variables, and reliability was measured using Cronbach's alpha (α) (Cronbach, 1951), composite reliability (CR) (Hair et al., 2017), and average variance extracted (AVE) (Hair et al., 2017). The reliability test results appear in Table 1.

Table 1. Reliablity test

Latent variable	Factor loading for MV	Cronbach's alpha ($\alpha > 0.7$)	CR (CR > 0.7)	AVE (AVE > 0.5)
Educational	0.839 - 0.950	0.893	0.934	0.827
Economic	0.762 - 0.945	0.831	0.901	0.753
Energetic	0.492 - 0.944	0.894	0.916	0.694
Ecological	0.884 - 0.958	0.833	0.919	0.850
Digitalization	0.693 - 0.953	0.863	0.906	0.710

When the reliability demands on the latent variables were verified, the discriminant validity test was performed. The results of the discriminant validity tests, which consisted of examining the cross-loadings, are given in Table 2. Manifest variables demonstrate discriminant validity when their cross-loading factors for a certain latent variable are higher than those for other latent variables (Hair et al., 2017). The measuring model is thus determined to be precise and reliable.

Table 2. Discriminant validity test

	Latent variable				
Manifest variable	Educational	Economical	Eneretical	Ecological	Digitalization
Advanced education rate	**0.934**	0.571	0.068	0.374	0.683
Labor force rate	**0.839**	0.514	0.209	0.242	0.727
Working-age population rate with advanced education	**0.950**	0.593	0.071	0.359	0.711
GDP per capita	0.615	**0.945**	0.154	0.552	0.703
GDP per worker	0.446	**0.886**	0.161	0.632	0.558
Research and development expenditure	0.521	**0.762**	0.360	0.243	0.643
Electricity generation from coal	-0.080	0.029	**0.791**	0.115	-0.002
Electricity generation from oil	-0.013	0.028	**0.492**	0.067	0.005
Electricity generation from other renewables	0.140	0.308	**0.944**	0.084	0.304
Electricity generation from solar	-0.011	0.161	**0.930**	0.046	0.147
Electricity generation from wind	0.177	0.210	**0.919**	-0.012	0.241
GHG emissions	0.245	0.432	0.033	**0.884**	0.213
CO_2 emissions	0.385	0.552	0.049	**0.958**	0.349
Active mobile-broadband subscriptions	0.618	0.480	0.129	0.136	**0.799**
Fixed broadband subscriptions	0.729	0.716	0.276	0.299	**0.902**
ICT index	0.790	0.788	0.292	0.371	**0.953**
Secure Internet servers	0.415	0.408	0.156	0.228	**0.693**

The previous results after testing the PLS-SEM model verify the validity of developing the importance-performance map. The PLS-SEM algorithm was configured to perform 3000 iterations. The cumulative impact and efficacy measurements appear in Table 3.

Table 3. IPMA performance score of latent variables and manifest variables

Latent variable	Total effects	Performance (0-100)	Manifest Variable	Total effects	Performance (0-100)
Social	0.534	56.001	Advanced education rate	0.190	63.019
			Labor force rate	0.202	51.688
			Working-age population rate with advanced education	0.197	50.210
Economic	0.454	37.030	GDP per capita	0.194	26.540
			GDP per worker	0.153	21.755
			Research and development expenditure	0.177	37.031
Energetic	0.083	8.683	Electricity generation from coal	0,000	9.616
			Electricity generation from oil	0,001	13.009
			Electricity generation from other renewables	0,039	10.050
			Electricity generation from solar	0,019	6.085
			Electricity generation from wind	0,031	9.152
Ecological	-0.124	27.561	GHG emissions per capita	-0.050	35.180
			CO_2 emissions per capita	-0.083	23.282
Digitalization	1	58.546	Active mobile-broadband subscriptions	0.263	39.177
			Fixed broadband subscriptions	0.340	53.373
			ICT index	0.368	59.659
			Secure Internet servers	0.190	8.341

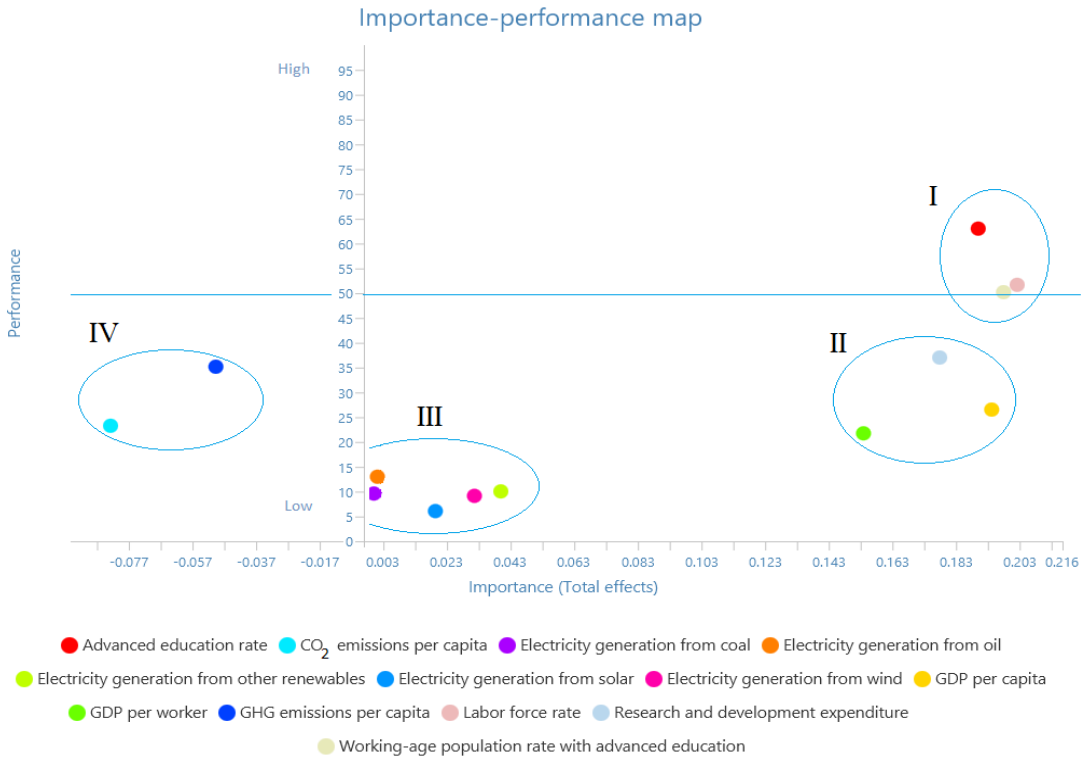

Figure 1. IPMA analysis of the manifest variables

Figure 1 displays a graphical representation of the IPMA for the manifest variables with respect to digitalization. Manifest variables that belong to a particular latent variable can be allocated to groups from I to IV.

5. DISCUSSION

According to the IPMA's research, the existence of educational latent variables has a statistically significant positive effect on digitalization, as evidenced by a performance score above 50. This latent variable is linked to the square matrix, where both importance and performance are high. The analysis suggests that a one-point increase in educational latent variable performance leads to an increase in the performance of digital development in the size of the total effect, which is 0.534. The importance of education for further digital development is also recognized by Van Laar et al. (2017). The economic latent variable has a slightly lower level of significance and lower performance. The matrix categorizes this latent variable as having low performance but high relevance, with a performance score that does not exceed 50. The results suggest that by increasing the performance of the economic latent variable by one point, the performance of digital development would increase by 0.454. The results for economic dimesion are confirmed in previous research by Fernández-Portillo et al. (2020). The latent variable related to energy has been determined to have the least significant positive influence. This variable demonstrates poor performance with minimal beneficial influence on digital advancement. The ecological latent variable has a negative value on the significance axis, indicating a score below 50, which suggests a low level of performance. The IPMA suggests that an increase in the performance score of the ecological latent variable would lead to a decrease in digital development. The results are confirmed by Ulucak et al. (2020) who proved the negative correlation between the digital development and environmental pollution. The IMPA is usually used for variables with positive effect in order to simplify the results discussion (Hair et al., 2018). Latent variables marked as group II (economic) and group IV (ecological) require additional attention since their effects (positive or negative) on digital development are high but their performance should be improved.

Examining the manifest variables reveals that the rate of advanced education outperforms all other variables that establish educational latent variables. This result is somewhat expected, as education is the foundation of any advancement or change, along with human resources. Alper and Alper (2020) confirm these findings by highlighting the fact that individuals's education skills should be updated regularly in order to satisfy future labor market demands. The IPMA assessment results indicated a significant level of performance for all three items, ranging from 50 to 63 points, along with strong positive total impacts above 0.19.

The IPMA study showed a substantial overall impact and slightly poorer performance in economic manifest variables. The metric of R&D is prioritized as an overall superior metric compared to the other two metrics of GDP. IPMA's visual analysis reveals that the items in issue have a positive effect on the development of digitalization, leading to performance levels that range from 21% to 37%. Watanabe et al. (2016) suggest that previous studies may have overlooked the contribution of the ICT industry to GDP, potentially contributing to the poorer performance of GDP variables. The Internet eliminated geographical boundaries and enabled individuals to freely access and utilize the knowledge and technology of others without financial compensation. Consequently, a significant amount of GDP is lost due to the inadequate protection of intellectual property rights (IPR) for ICT discoveries or products (Watanabe et al., 2016).

Overall, energy-related manifest variables have a minimal impact on digital progress. Solar electricity generation, as a renewable energy source, has the lowest performance (<10%) among the considered energy generation options. In contrast, other types of energy generation from fossil fuels attain higher performance. Enhancing the performance of these manifest variables would not yield a substantial impact on the advancement of digitalization. Previous studies confirm the rising trend of energy consumption in digitally developed environments (Koot & Wijnhoven, 2021).

The IPMA graph demonstrates that greenhouse gas (GHG) and carbon dioxide (CO2) emissions negatively impact the process of digitalization development, leading to low performances of both manifest variables. This suggests a correlation between a decrease in emissions and a rise in digitalization. This phenomenon is observed in several advanced economies (Ma et al., 2022).

6. CONCLUSION

The present research paper addresses multiple effects on digital development that consist of education, economy, energy, and ecology. The survey was carried out in European nations from 2010 until 2016. The primary theoretical contribution of this study lies in the application of a visual tool to evaluate the predictive capacity and effectiveness of the four dimensions of digital development. The IPM methodology emphasizes the significance of individual dimensions and its effectiveness in assessing digital growth, which is currently lacking in the existing literature on digitalization.

Existing research yields several practical implications. Education is a fundamental component of prosperity in a digital society. Therefore, it is essential to invest in digital literacy and digital resources that may be integrated into educational systems. Considering the significance of GDP and R&D spending in driving digital advancement, the government should prioritize establishing financial incentives to encourage enterprises to participate in digital development initiatives. According to the IPMA results, there is evidence of a negative relationship between the ecological latent variable and digital progression. Therefore, one of the government's strategic goals should be to invest in digital innovation and develop smart cities and other aspects of the economy that would reduce pollution and decrease carbon footprints.

The primary constraint of the article is the limited number of variables considered in the analysis, which encompass the four aspects of the digitalization process. This constraint can be alleviated by including supplementary indicators that encompass various features of the dimensions. The results of the energetic latent variable analysis indicate a lack of performance and a minimal overall impact on digital development. Therefore, it is recommended that future studies focus on investigating the relationship between energy and digitalization in more detail.

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POTENTIAL ASPECTS OF CLOUD-BASED RISKS AND PROTECTION STRATEGIES

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Abstract: This study delves into the security issues associated with cloud technology, which jeopardize the safety of our data stored in the cloud. The widespread adoption of cloud technologies has significantly increased exposure and vulnerability to security threats, despite the convenience features it offers to users. Although cloud technology is generally considered secure, it still contains inherent security risks that users must be vigilant about. The level of users' awareness regarding these risks is crucial in mitigating potential security breaches and safeguarding sensitive information. Adequate training and education regarding cloud security measures can empower users to make informed decisions and take proactive steps to protect their data. Security incidents in cloud environments can have far-reaching consequences, impacting not only individual users but also organizations and their stakeholders. Therefore, users need to stay informed about emerging security threats and implement best practices to minimize their exposure to risks. Collaborative efforts between cloud service providers and users are necessary to continuously improve security measures and adapt to evolving cyber threats. By fostering a culture of security awareness and proactive risk management, we can better protect our data and maximize the benefits of cloud technology.

Keywords: Cloud computing, Security risk, Data storage, Security awareness, Cyber security.

1. INTRODUCTION

The use of cloud services is extremely beneficial for both personal and business purposes. Cloud offers users flexibility, scalability, and cost-effectiveness. However, alongside its advantages and widespread adoption, the technology requires special attention to the IT security challenges it poses. Cloud-based security deals with identifying, managing, and preventing risks associated with services. Its goal is to protect data, applications, and

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infrastructure stored in the cloud. This includes discussing security issues related to deployment models, service models, and finally, best practices.

2. SECURITY ISSUES OF SERVICE MODELS

Security issues of service models include limited control, which allows users to monitor and modify certain components of the underlying infrastructure, potentially restricting users' abilities to implement security measures and leaving the protection to the cloud service provider. Another problem is configuration errors, which occur when users incorrectly set security parameters, posing serious security risks such as leakage of sensitive data and unauthorized access to data.

2.1. Security Issues of Public Cloud

When using public cloud services, we must face several security challenges. Public cloud services enable a multi-tenant environment, meaning the provider offers public services accessible to anyone, but multiple tenants can use them simultaneously, with the provider distributing its resources among tenants based on their needs. As the number of users increases, so do the security risks. Due to the multi-tenant infrastructure, data leakage between tenants can occur. It becomes particularly problematic when authentication data and keys are stored in the cloud because, in the event of a hacker attack, encrypted data can become readable. Although the data is stored with the provider, it cannot completely rule out the possibility of an internal attack, where unauthorized individuals can gain access to sensitive information and data (Takabi & GhasemiGol, 2019)

2.2. Security Issues of Private Cloud

Compared to public clouds, private clouds offer increased security, better data protection, improved performance, and greater customization. Of course, this model also has its security challenges. The most common security issues of private clouds include:

- Data loss: Data loss can occur due to security breaches, human error, malicious software, or hardware failures.
- Internal threats: Internal users can abuse their privileges, causing harm to systems or accessing data unauthorizedly.
- Misconfigurations: Configuring private clouds is a complex task requiring a highly skilled team for proper configuration. Configuration errors can be exploited by external attackers.
- Inadequate maintenance: Regular maintenance and security updates are essential tasks. Neglecting these can lead to vulnerabilities.
- Physical security: Physical security of the private cloud infrastructure is also important. The physical infrastructure must be made inaccessible to attackers (internal or external) (Kumar & Vajpayee, 2016).

3. SECURITY ISSUES OF IAAS

Denial of Service (DoS) attacks involve overwhelming a specific server with a large volume of data traffic, preventing legitimate requests from being fulfilled, which can ultimately lead to decreased performance or even a complete shutdown of cloud-based applications and

services. Limited control in cloud services restricts users from monitoring and modifying certain infrastructure components, potentially hindering their ability to implement necessary security measures and leaving them reliant on the provider's security protocols. Misconfigurations, often stemming from users incorrectly setting security parameters, pose significant risks in the Infrastructure as a Service (IaaS) model, potentially resulting in sensitive data leaks, unauthorized access, and other security incidents that compromise the integrity of cloud-based systems (Jones, 2023; Alouffi et al., 2021, Zhang et al., 2019; GhasemiGol, 2019).

3.1. Denial of Service (DoS) Attacks

DoS attacks are overload attacks where a single computer attacks a specific server. Attackers inundate resources with a large amount of data traffic, thereby preventing legitimate requests from being answered. A successful DoS attack can result in decreased performance or even a complete shutdown of applications and services running on cloud resources.

3.2. Limited Control

Limited control means that service users have limited access to monitoring and modifying certain components of the underlying infrastructure, despite having control over virtualized resources. This limitation can restrict users from implementing security measures, thus relying on the cloud service provider.

3.3. Misconfigurations

Misconfigurations occur when users incorrectly set security parameters. In the IaaS model, users are responsible for configuring their virtual machines and other resources. Access permissions, network settings, and security group rules are areas prone to misconfiguration errors. Misconfigured security settings pose serious risks, such as leakage of sensitive data, unauthorized access to data, and other security incidents.

3.4. Bypassing Virtual Machines, Containers

Bypassing virtual machines and containers involves exploiting a security flaw where attackers can penetrate the hypervisor's security layer to access other machines or hosts. This can result in severe security issues, including service disruptions, unauthorized access to personal data, or attacks against virtual machines or systems.

3.5. Captured, Acquired Identities

When attackers obtain user authentication data, those identities are compromised. Attackers can then impersonate legitimate users using the acquired credentials, gaining unauthorized access to virtualized resources.

3.6. Compliance, Regulatory Requirements

In this environment, the provider must comply with industry-specific regulations, standards, and internal security policies. It is the user's responsibility to choose a provider that meets these requirements. Selecting an inadequately compliant provider or disregarding regulations can lead to legal sanctions and fines.

4. SECURITY ISSUES OF PAAS

Data breaches and data security in Platform as a Service (PaaS) environments pose significant risks, especially when developers mishandle access keys, potentially leading to the leakage of sensitive information to unauthorized parties. Platform vulnerabilities in PaaS services, such as flaws in the infrastructure or runtime environment, provide attackers with opportunities to exploit weaknesses, resulting in unauthorized access, data breaches, and system disruptions. Application vulnerabilities, such as coding errors, leave PaaS applications susceptible to exploitation by malicious actors, potentially leading to unauthorized access, data breaches, and other illicit activities that compromise system security (Rastogi et al., 2018; Thabit et al., 2020).

4.1. Data Breaches and Data Security

Storing and processing sensitive data in PaaS poses security risks. For example, if developers mishandle database access keys, sensitive data and confidential information can leak out, falling into unauthorized hands.

4.2. Platform Vulnerabilities

Vulnerabilities in PaaS services refer to security flaws found in the underlying infrastructure, runtime environment, or services that attackers can exploit. This can lead to unauthorized access, data breaches, disruptions, and other damages in the PaaS environment, endangering system security and stability. Moreover, attackers can gain access to sensitive information, cause service outages, or inflict other harm.

4.3. Application Vulnerabilities

Application vulnerabilities, such as faulty coding, can be exploited by malicious actors. For instance, inadequate handling of user input can make an application vulnerable to SQL injection attacks. Upon successful exploitation, attackers can gain unauthorized access, perform data breaches, and execute other illegal operations.

4.4. Limited Visibility

PaaS users lack complete visibility into the underlying infrastructure and the security measures implemented by the provider. This deficiency makes it challenging to identify security gaps and respond effectively when necessary.

5. SECURITY ISSUES OF SAAS

The security issues of Software as a Service (SaaS) typically revolve around data privacy, access control, and account security. For instance, inadequate authentication mechanisms or weak password policies can lead to unauthorized access to sensitive data stored in SaaS applications. Additionally, vulnerabilities in the SaaS provider's infrastructure or application code can be exploited by attackers to compromise data integrity or launch cyberattacks against users (Michon, 2017; Cyber Security News, 2023).

5.1. Data Storage

When utilizing SaaS services, users essentially entrust their confidential data to a third party. Whether for corporate or individual use, sensitive data is often involved, making its protection critically important. Data storage occurs on servers owned and managed by a third party rather than the user. Improper storage can lead to unauthorized access to data, potential data breaches, or other security threats, especially if the provider fails to implement adequate security measures. Additionally, since data is stored in the cloud, it is susceptible to factors such as network connectivity issues, hardware failures, natural disasters, data loss, or corruption. It's essential to highlight the risks of over-retention, where the provider does not retain data for the agreed-upon duration (e.g., in case of service termination), potentially resulting in the leakage of confidential information. Compliance with data retention guidelines is the provider's responsibility; however, it's not uncommon for sensitive and confidential information to be over-retained despite regulations.

5.2. Regulatory Compliance

Different industries and sectors have varying cybersecurity compliance requirements, which are defined by standards. Compliance is not only a legal obligation but also essential for protecting a company's data and reputation. Non-compliance with standards can lead to legal penalties, data breaches, financial losses, and damage to the company's reputation. For example, in Hungary, financial service providers must comply with the regulations outlined in the DORA decree, which ensures greater resilience against cyberattacks in the financial sector. Healthcare providers are subject to different standards and requirements (The Recommendation No. 4/2019 (IV.1.)). These regulations evolve continuously with technological advancements and the increasing threat of cyberattacks. Therefore, businesses must stay up to date with the latest standards and regulations.

5.3. Shadow IT

Shadow IT refers to the unauthorized use of IT systems, software, applications, or devices. Within organizations, it involves employees or departments using SaaS solutions that have not been approved by the IT department. With the widespread adoption of remote work, it has become increasingly acceptable for employees to use their laptops or mobile phones for work at the workplace. If the tools provided by the company are not user-friendly or lack sufficient functionality, employees may install unauthorized applications that offer more features and are easier to use than approved ones. Employees also often install unauthorized applications on company devices. While this may make individual tasks easier, it poses a significant risk to the company's network security. Shadow IT is a significant concern as applications installed in this manner may not necessarily comply with the company's security requirements and may hinder the supervision and control of the IT department.

5.4. Insider Threats

Access management also presents SaaS security risks to companies, as it involves controlling and managing access to sensitive data and applications for employees, customers, partners, or other stakeholders. If access management is not properly implemented, it can lead to unauthorized access, data breaches, and other security threats. Within a company, obtaining access credentials of a single user is enough for attackers to gain unauthorized access to

sensitive data. This can occur due to human error, whether accidental or intentional. Attackers can obtain a user's data by enticing them to click on a link hidden in a well-crafted email, or they may offer various goods in exchange for the user's login credentials. Additionally, a company may fail to revoke the access privileges of a former employee, allowing them to misuse their active permissions.

5.5. Third-Party Risk

While integrations from third parties enhance functionality (e.g., integration with a CRM system), they may also carry vulnerabilities. Integrating services from inadequately protected third parties can pose potential threats to users of SaaS applications.

5.6. Misconfigurations in Cloud Services

Due to the complexity of cloud-based infrastructure, there is a risk of misconfiguration or missing an important setting. Most SaaS products have configuration interfaces that users must set up themselves. Improper data protection settings harbour significant vulnerabilities since a popular service may be used by thousands or even millions of people daily. Even simple cases, such as the absence of MFA configuration or excessive data access provided by administrators to users, can pose vulnerabilities. Misconfigurations can easily lead to serious security incidents.

5.7. Insecure APIs

Application Programming Interfaces (APIs) facilitate communication between various software components. Every application we use on our mobile phones or computers and every website we browse likely utilizes APIs. Security APIs determine who can access what data and how. They can restrict operations and decide who has permission to perform a specific operation, including reading, modifying, or deleting data, thus exerting significant influence on data availability and the protection of users' data. Attackers favour APIs as they can easily access a large amount of sensitive data relatively simply. Vulnerable APIs, widely used today, are one of the most critical security risks.

5.8. Account Takeovers

In the case of an account takeover, unauthorized individuals gain access to sensitive data through compromised user accounts, potentially resulting in significant losses, financial damages, or identity theft. Typically, hackers gain control over a user's account by cracking weak passwords or exploiting security vulnerabilities.

5.9. Denial-of-Service (DoS) and Distributed Denial-of-Service (DDoS) Attacks

Denial-of-Service (DoS) and Distributed Denial-of-Service (DDoS) attacks are two common cybersecurity threats aimed at partially or completely disabling a computer, network, or service, disrupting its normal operation. During a DoS attack, the attacker overwhelms the target using a single system (typically by generating a large amount of data traffic), which can slow down or even halt the system's operation. In a DDoS attack, multiple compromised computers are used to send requests to the targeted destination's IP address, thereby overloading

it. These attacks pose significant risks to users as they prevent access to the service, potentially causing significant financial damage, for example, in the event of a service outage.

5.10. Zero-Day Threats

Zero-day vulnerability refers to security flaws in software that developers are unaware of (they haven't noticed the flaw), but the software has already been released for use. Attackers exploit the vulnerability in the application until the security flaw is patched. The zero-day starts when the developer becomes aware of the flaw but has not had the opportunity to fix or distribute it to users. These flaws can lead to data leaks and unauthorized access.

5.11. Virtualization Risks

In a multi-tenant environment, multiple clients use the same instance of software deployed across multiple servers. User data and resources are located in a computing cloud, distinguished and controlled by unique identifiers. Risks arise from multi-tenancy environments because multiple clients use the same hardware. Improper data segmentation can lead to data leaks or security breaches. Inadequate data segmentation may allow hackers to access the data of one user, thereby gaining access to the data of multiple users.

6. EFFECTIVE STRATEGIES FOR ENHANCING CLOUD SERVICE SECURITY

Effective strategies for enhancing cloud service security may include implementing multi-factor authentication, regularly updating security patches, and conducting thorough security audits. By employing encryption techniques for data both in transit and at rest, organizations can bolster their cloud security posture. Additionally, fostering a culture of security awareness and providing comprehensive training for employees can further strengthen cloud service security measures (Ádám et al., 2024; Barta & Nyikes, 2024).

6.1. Multi-factor authentication

Multi-factor authentication (MFA) enhances the security of cloud services by requiring users to provide multiple forms of identification to access their accounts. This additional layer of security significantly reduces the risk of unauthorized access, even if one factor, such as a password, is compromised. MFA typically combines something the user knows (like a password) with something they have (like a smartphone or token) or something they are (like a fingerprint or facial recognition). Implementing MFA ensures that even if one factor is breached, attackers still need additional information to gain access, making it a highly effective security measure. Organizations can leverage MFA across various cloud services to safeguard sensitive data and protect against cyber threats more effectively (Basan, 2023).

6.2. Studying the Shared Responsibility Model

Responsibility for maintaining system security and operation is shared between the cloud service provider and the user. The responsibilities of the user and provider vary depending on which service model the user is using and whether an on-premises or public data centre is operated. This responsibility model is typically made publicly available by leading cloud service providers (e.g., Microsoft.com), along with explanations. Users need to study and

understand their areas of responsibility to avoid misunderstandings and inadequate security settings (Illési & Honfi, 2022). Cloud service providers have robust security measures, and if customers take the necessary steps (such as data encryption, and proper configurations), their data remains secure.

6.3. Comprehensive Evaluation of the Cloud Service Provider's Security Strategy

The chosen cloud service provider needs to have security documentation and security operations that can be applied in the event of an incident. I reviewed the security documentation of two major providers (Google and Microsoft). Both companies provided clear answers on who has access to my online stored data, where they are stored, how to keep them secure, and what to do if my account is compromised. Naturally, detailed information on data encryption, disaster recovery, incident management, and other techniques is also available and documented comprehensively and understandably (Tick et al., 2022; Bús & Nyikes, 2024). Considering the following points before choosing a provider can help gain a more comprehensive understanding of the cloud service provider's security strategy:

- Security certificates and standards
- Data privacy policies and regulations
- Service interruptions and availability
- Physical security
- Security incident management

6.4. Applying Identity and Access Management (IAM) Solutions

Unauthorized access poses a significant threat to the security of public clouds. To minimize risks, organizations should consider implementing IAM solutions. Identity and Access Management (IAM) solutions are systems that enable user identification and access management to IT systems and resources. It's worthwhile to employ IAM solutions capable of operating in both private data centres and cloud environments, thereby enabling unified user identification and policy enforcement in the IT environment. The IAM system authenticates users and either grants or denies access to specific resources. In practice, IAM systems typically require a combination of the following capabilities:

- Seamless registration and login
- User authentication from various sources: Users should be able to authenticate themselves with accounts from different providers. For example, Google's authentication service allows users to sign in to other websites without new registrations.
- Multi-factor authentication (MFA): Protects user accounts even if attackers have obtained login credentials. MFA provides additional verification steps, such as SMS confirmation or biometric data authentication.
- Role-Based Access Control (RBAC): Access for users within an organization is based on their unique positions, so an IT specialist and an administrator do not have the same access. With RBAC, individuals with the same role have the same access.
- Principle of least privilege and least trust: This principle operates on the lack of trust, minimizing users' access to systems and restricting them to the permissions necessary to perform their tasks.
- Enhanced authentication: Access to sensitive information requires stronger identity verification than accessing everyday data.

6.5. Employee Training

As virtually every company, from small businesses to multinational corporations, uses cloud services nowadays, it has become necessary to increase employees' cybersecurity awareness. Now more than ever, it's important for employees to be aware of common cybersecurity threats and know how to protect their own and company data. In most cases, risks originating from users are unintentional, so with proper training and motivation, the risks of security incidents can be reduced (Nyikes et al., 2022). During education, it's advisable to focus on the following topics:

- Identifying cybersecurity threats (e.g., phishing, ransom ware)
- Creating and managing strong passwords
- Recognizing and avoiding social engineering attacks
- Understanding the concept and risks of shadow IT
- Using unauthorized devices and applications
- Principles of data privacy and confidentiality
- Safe browsing practices

6.6. Endpoint Protection

The use of cloud services increases the demand for effective endpoint security, as endpoints often connect directly to the cloud. Often, users' devices (e.g., laptops, smartphones, and other devices) connect directly to the cloud, bypassing corporate firewalls or other security devices. New cloud projects aiming to introduce or expand cloud services present new challenges in terms of cybersecurity. Effective endpoint protection in the cloud is essential for protecting corporate data and minimizing cybersecurity risks. Effective endpoint security solutions may include pre-installed security software, as well as firewalls and encryption solutions running on devices.

6.7. Data Encryption during Storage and Transmission

Encrypting data is crucial not only for stored data but also during data transmission. Cloud service providers encrypt stored data, but most providers do not employ end-to-end (e2e) encryption. When sensitive data is uploaded to the cloud without e2e encryption, it can be visible during transmission if a hacker monitors it, such as when data traffic occurs over public Wi-Fi networks. Furthermore, after storage, data can become decipherable in the event of a successful hacker attack. However, if a provider that utilizes e2e encryption is employed, data is encrypted on our devices before transmission, with only the owner knowing the encryption key, and the provider cannot access the data. Thus, even if the provider experiences a hacker attack, our data remains unreadable to hackers. It is recommended to choose a provider that meets our data security requirements.

6.8. Regular Inspection of Security Logs

One of the most effective cloud security solutions today is enabling and inspecting security logs. In addition to logging cloud service activities, companies should bring these data into a centralized system capable of monitoring and responding (SIEM). SIEM (Security Information and Event Management) allows for the collection, interpretation, and analysis of security information and events in a central location. With this system, events and information from multiple sources are collected and analysed to identify security incidents, threats, or other

issues. Logging assists system administrators and security teams in monitoring user activities and detecting unauthorized activities that would be impossible to achieve manually. In the event of a successful attack, a SIEM tool enables rapid recovery to limit damage.

6.9. Identification and Remediation of Misconfigurations

Security in SaaS (Software as a Service) is an important area that every organization should consider. Misconfigurations and misconfiguring applications can lead to cybersecurity threats, so identifying and remedying them is crucial. These threats become increasingly difficult to detect as the organization grows. Organizations are advised to continuously monitor their applications and proactively manage security risks. This includes identifying and fixing misconfigurations, as well as implementing appropriate security measures to prevent future errors.

7. CONCLUSION

The use of cloud services is extremely beneficial for both personal and business purposes. Cloud offers users flexibility, scalability, and cost-effectiveness. However, alongside its advantages and widespread adoption, the technology requires special attention to the IT security challenges it poses. Cloud-based security deals with identifying, managing, and preventing risks associated with services. Its goal is to protect data, applications, and infrastructure stored in the cloud. This includes discussing security issues related to deployment models, service models, and finally, best practices. Security issues of the public cloud include the possibility of a multi-tenant environment. Public cloud services enable a multi-tenant environment, meaning multiple clients can use the service simultaneously. As the number of users increases, so do the security risks. Due to the multi-tenant infrastructure, data leakage between tenants can occur. It becomes particularly problematic when authentication data and keys are stored in the cloud. Although the data is stored with the provider, it cannot completely rule out the possibility of internal attacks. Compared to private clouds, public clouds increase security risks. The most common security problems include data loss.

Data loss can occur due to security breaches, human errors, malicious software, or hardware failures. Employees can abuse their privileges, causing harm to systems or accessing data unauthorizedly. Configuration errors can be exploited by external attackers. Regular maintenance and security updates are essential.

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ENHANCING PRODUCTION PLANNING EFFICIENCY WITH DOCUMENT MANAGEMENT USING BPM TOOLS - THE BONITA APPROACH

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Abstract: The efficient implementation of business process automation (BPA) through modern business process management (BPM) tools requires a comprehensive approach. This includes analyzing existing business processes to identify shortcomings and potential areas for improvement. Additionally, it involves designing optimized processes aligned with the overall business strategy of the company. Utilizing BPM tools for business process automation becomes imperative to improve efficiency, minimize errors, and elevate overall company performance. This paper explores the pivotal role of process automation in production planning within the industry, with a specific focus on utilizing BPM tools like Bonita. By analyzing the challenges in effective production management and the need for documentation optimization, the problem of inefficient paper document flow is identified. Through a detailed analysis of the production planning process and the application of a methodology involving Bonita software, a conceptual solution is presented. The result is a process diagram illustrating the benefits of automating the production planning process, including improved efficiency, reduced documentation processing time, and simplified process tracking. This paper contributes to understanding the importance of BPM tools like Bonita in modernizing and optimizing production processes, thereby promoting competitiveness and operational excellence in today's business environment.

Keywords: Business process management (BPM), Production planning, Process automation, Document management, Bonita software

1. INTRODUCTION

A business process consists of various activities utilizing diverse inputs to produce valuable outputs for customers. From the viewpoint of process innovation, a business process

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is a purposefully structured and consistently executed series of activities aimed at achieving specific outcomes for a targeted market or customer base (Senkus et al., 2021). The concept of process is central to various initiatives such as customer relationship management, enterprise resource planning, and business process management (BPM) (Smart et al., 2009; Katuu, 2020).

BPM involves the strategic oversight of how tasks are carried out within an organization, aiming for consistent results and seizing opportunities for enhancement (Reijers, 2021). The BPM lifecycle involves iterative steps such as modeling business processes, developing software to support them, executing these processes, and evaluating their performance (Calegari & Delgado, 2018). The primary objectives include reducing costs, enhancing quality, and increasing productivity and competitiveness relative to other organizations in the same industry (Meidan et al., 2016; Butt, 2020).

BPM, regarded as a method for continuous improvement, is widely adopted by numerous organizations across various industries. Recognizing the importance, organizations strive to implement well-defined processes to enhance maturity levels and improve product development and management, thereby enhancing quality. Currently, there exists a diverse range of software tools known as Business Process Management Systems (BPMS), facilitating the management of the business process lifecycle and simplifying BPM applications in business settings (Meidan et al., 2016; Ubaid & Dweiri, 2020).

BPMSs are designed to execute and manage business processes using visual diagrams. They enable the visualization of information flows, facilitate analysis, support process improvement initiatives, simulate processes, and enable automation where applicable (Araujo & Gomes, 2023).

Effective production management hinges on access to timely and accurate information about the system's condition and behavior over time. A well-designed computer-supported information system is crucial for integrating and coordinating the functions of a production-business system. Without it, achieving unified and harmonized operation becomes challenging, if not impossible (Arromba et al., 2019; Vafaei-Zadeh et al., 2020).

Documentation plays a crucial role in production, as it enables a clear definition of processes, optimal resource utilization, performance tracking, and prompt response to any changes or issues (Yarbrough et al., 2022). Therefore, it is important for manufacturing companies to carefully manage their documentation to ensure successful and efficient operations.

Empirical evidence from the field of BPM highlights successful applications of these practices in Slovenia and Serbia. In Slovenia, the focus of BPM is on enhancing customer satisfaction and expanding market share, supported by early adoption of EU standards and a long-standing tradition of an open market. In Serbia, the main driver for implementing BPM is obtaining Quality Management System (QMS) certification, often a necessity for international collaboration. While QMS certification is just an initial step, it paves the way for fundamental improvements in business processes (Stojanović et al., 2017). For both countries, BPM is crucial for enhancing operational efficiency, which is essential for strengthening global competitiveness. This confirms the vital role of BPM not only in meeting international standards but also in promoting deep, strategic business improvements.

The research will emphasize the significance of automating the production planning process within a manufacturing company in Bosnia and Herzegovina. Utilizing the BPM tool Bonita, the paper will culminate in the development of a BPM application designed to support the management of production documentation flow. Additionally, it will feature a process diagram illustrating a conceptual solution for optimizing and innovating the production planning process.

This paper highlights the importance of implementing BPM tools like Bonita, which significantly automate and optimize production planning processes, reducing manual labor, errors, and enhancing efficiency. A focus is placed on document management, a crucial element for defining processes, optimizing resource utilization, and providing rapid responses to changes. The introduction of such technologies in Bosnia and Herzegovina not only improves existing processes but also fosters innovations in the manufacturing sector, inspiring other companies in the region to adopt similar technological solutions, leading to increased transparency, efficiency, and market competitiveness.

The paper comprises six sections. The second section provides an overview of relevant research, highlighting the importance of Business Process Management (BPM) and Business Process Management Systems, particularly in managing production document flow. Section 3 focuses on the production planning process and identifies documents targeted for automation. The fourth section introduces the methodology for developing the proposed solution, emphasizing the use of Bonita software for Business Process Automation (BPA) in production planning. Section five presents the proposed solution through a process diagram, outlining its necessity and benefits. Finally, section six concludes the paper and suggests avenues for future research.

2. RELATED WORK

The following chapter provides an overview of existing research and initiatives relevant to the theme of BPM, BPMS, and the flow of production documents.

Over the last decades, technology has permeated nearly every aspect of everyday life, including the business landscape (Ko et al., 2009; Cimino et al., 2024). Companies constantly strive to navigate business transformations, prioritizing agility and efficiency. Consequently, implementing BPM emerges as an essential strategic initiative, offering substantial advantages for both customers and companies. Businesses that adopt BPM aim to simplify their operations, including boosting revenue and profitability, cutting operational expenses, enhancing customer service, minimizing waste and redundancy, managing risks, and ensuring compliance with policies and regulations (Djedović et al., 2016; Neubauer et al., 2014; Pereira et al., 2019; Barbu et al., 2020).

The manufacturing sectors in companies generate a heap of production papers. In these digital times, manual paper forms have progressively transitioned to their digital equivalents, which resulted in the creation of the DMS (Document Management Systems), which then evolved into BPM (Pereira et al., 2019).

DMS was originally designed to digitize paper documents, tackling a widespread problem in various industries. This excess paper generation resulted in decentralized costs and repetitive tasks like duplicative data entry across information systems (IS). However, modern DMS solutions have expanded beyond basic document digitization and retrieval (Pereira et al., 2019).

BPMS is a software suite that integrates business procedures and processes. Through the adoption of BPMS, companies can automate repetitive and mundane tasks and activities, as well as improve customer satisfaction, partly supporting the BPM lifecycle (Alotaibi & Liu, 2017).

The BPM lifecycle consists of five key stages: design, modeling, execution, monitoring, and optimization. Each stage builds upon the last, culminating in a streamlined and responsive business process management system tailored to meet organizational objectives which when followed by organizations, enables continuous enhancement and alignment of processes with strategic goals (Lee & Dale, 1998; Rehse et al., 2018).

However, BPMSs do not provide full support for this lifecycle which makes it more difficult to choose the right BPMS (according to the needs of the organization).

BPM tools enable employees who are not working in the field of information and communication technologies to create automated workflow systems. According to the researchers, the most popular software for the implementation of business process management includes Bonita, Bizagi, and Camunda. There are more BPMS platforms, but these three are the most cited ones (Alotaibi & Liu, 2017; Calegari & Delgado, 2018). Automating process management presents numerous options in pricing and features. Consequently, choosing the appropriate solution can be a complex task, requiring a comprehensive analysis of the most notable available options (Meidan et al., 2016).

Bonita has garnered attention as a robust BPM tool capable of integrating seamlessly with document management systems to enhance production planning efficiency (Meidan et al., 2016).

The paper uses this particular BPM tool to automate document flow in a production planning environment and enhance performance. A detailed overview will be provided in the subsequent section.

3. PRODUCTION PLANNING PROCESS AND DOCUMENT MANAGEMENT

As mentioned in the previous chapter of this paper, information and communication technologies have transformed almost every aspect of business, including the production division. Companies not only embrace those technological changes but constantly strive to utilize new technological improvements in their businesses (Rehse et al., 2018; Peter et al., 2023) . Technological progress in production and resource management has led to alterations in manufacturing processes, distribution methods, and organizational structures within companies (Peter et al., 2023). Continuing to innovate technologies and enhancing prior existing ones becomes an even greater necessity for further industry growth.

The core of every manufacturing enterprise lies in a profound understanding of its processes and creating products for its customers. Based on observations within the company, refining and enhancing the production planning process and managing the flow of production documents are critical areas that require further analysis and improvement.

This section aims to describe the production planning process, highlighting the importance of the company’s production planning documentation and its flow through the manufacturing process. The accent is on the automation in generating production documents and transforming them into paperless forms using the Bonita BMP tool (Zelenović, 2004; Laudon & Laudon, 2017)

The purchase requisition, purchase order, operational plan, work orders, technological procedures, routing sheets, bill of materials, receipt and delivery cards, operation sheets, and return receipt are among the 10 documents that will be further automated and analyzed.

Customers initiate the process by placing an order requisition. The requisition consists of the chosen product and its quantity, as well as the necessary information about customers: name, surname, address, etc. After placing a purchase requisition, the company's sales department verifies it with a simple checkbox and creates a purchase order.

The first production planning document that ought to be created is the operational plan. It represents a production plan for products with specified quantities for a certain period. It carries information about the product.

The work order is the fundamental information carrier in the manufacturing process of parts and products. It bears the cost of producing parts, assemblies, and products. Upon

completion, the work order serves as the basis for analyzing the expenses and costs incurred during the process.

Technological procedures are documents that include operations' names and labels, as well as the technological systems where each operation is performed and the tools used. Additionally, the exact manufacturing times and total durations of the product's technological procedure are recorded.

The routing sheet is used for each product operation. It is closely related to work order.

The bill of material is an information carrier used to withdraw materials for production from the warehouse. It also has information similar to a work order, except the quantity of the material.

Receipt and delivery cards serve as a general basis for receiving or handing over parts during the workflow – confirming the completed reception process (handover of parts). It verifies the interoperation time intervals. The receipt and delivery cards are issued at all reception/handover points to ensure procedural coverage. It is also the last production planning document

The sole document within the production process is the operation sheet, containing information identical to the routing sheets. One crucial addition is an indication of any malfunction occurring in the technological system or tools during production.

The warehouse sector issues the last document in this process,the return receipt. It is used to return materials that have not been used in the production process.

Following the exposition of the researched business process, the next chapter will present the methodology used to formulate a conceptual solution for automating the documentation flow.

4. METHODOLOGY

A conceptual solution for automating the production planning process has been created, relying on an open-source business process management tool called Bonita. This solution aims to enhance process execution and improve overall business efficiency.

Bonita BPM is an open platform for managing business processes and workflows, enabling the development of highly engaging, personalized, process-driven business applications that adapt to real-time changes in business operations. It consists of three main components (*Bonita Components | Bonita Documentation*):

- Bonita Studio: The development environment,
- Bonita Runtime: The execution environment and
- Bonita Continuous Delivery: The tool to continuously deliver Bonita projects.

Bonita BPM Studio provides a graphical environment for creating processes and application pages. It includes three primary design tools (Nafie, 2016):

- Whiteboard: This tool is used for drawing process flow diagrams and defining step details, transitions, decision points and other process elements,
- Low-code development tools: These tools allow users to design data models, process-based applications, and sandbox organizations with ease and
- UI Designer: This tool is utilized to create application pages and process forms.

Bonita projects encompass various components crucial for process management and application development. These elements and their brief descriptions are presented in Table 1.

Table 1. Bonita project elements *(*Bonita Components | Bonita Documentation*)*

Element	Description
Process Elements	Bonita utilizes BPMN **diagrams** for visualizing business processes, along with web-based **forms** for user interaction. The **Actor Filter** assigns tasks to specific users or groups, ensuring authorized access. **Connectors** facilitate seamless integration with external services, automating data exchange and process orchestration.
Data	Business Data Model defines the structure and attributes of the data entities used within processes, facilitating consistent data management and ensuring data integrity throughout the process lifecycle.
Identity Management	Bonita provides tools for managing user identities within the system. This includes defining user roles, groups, and permissions to regulate access to processes and data. The organization module ensures proper authentication and authorization mechanisms are in place, enhancing security and governance.
Living Applications	The **Application Descriptor** in Bonita enables the creation of tailored pages for user profiles or functional needs, specifying configuration details like **layout, theme, and functionalities**. Developers can design custom web pages using **Application Pages** to enhance user experience and functionality. Bonita offers flexible **Layout** options for organizing application elements, optimizing usability and aesthetics. **Theme** customization ensures consistency and branding alignment across the application.

The specific concept employed is the use of contracts as interfaces, providing greater flexibility and agility. The role of the contract is to define the data that the process expects to execute a step or initiate a new instance. The web interface designer ensures that all necessary data are collected as input and then sent to the Bonita BPM Engine while it executes the process. The Bonita BPM Engine verifies the data received from the user interface against the contract. If the contract is not fulfilled, the execution engine disregards the request and can maintain the process in a stable and coherent state. If the contract is fulfilled, the process flow continues (Chabanoles & Ozil, n.d.).

Bonita software was used to design and implement proposals for improving business processes, following a detailed analysis of their current operations. The process starts with creating a business process model using BPMN standard for graphical representation. Then, data models are defined using Bonita BDM for efficient data management. Next, participants and their access resources are defined for successful implementation. Finally, Bonita UI Designer creates intuitive web interfaces for user interaction with the application.

The first step in implementing this solution in Bonita is defining the business process model. The process model was constructed by adding BPM elements, resulting in a fully operational application ready for testing and use via the Bonita portal. After the initial definition, a Pool named "Production Planning" was created, which serves as the main container in which the entire process flows. Within this pool, six Swimlanes are organized that reflect different groups of participants in the process. These lanes are: Customer lane, Sales department lane, Manufacturing director lane, Manufacturing department lane, Quality department lane, and Warehouse lane. Each lane enables clear organization and distribution of tasks within specific parts of the organization, thereby efficiently managing the process flow.

The BPM illustration clearly shows the process flow, starting with the initial event of submitting a purchase order request and ending with the final event of successfully completing production planning. The process consists of 12 steps, each requiring manual user intervention.

During the process execution, there are three XOR-type control points, implying that only one path is chosen based on predefined conditions.

For efficient data management through the BDM on the Bonita platform, the first step is to define all data types used in the business process thoroughly. Once these data types are identified, the next step is to create corresponding objects within the BDM. Business variables are key elements that link data models to actual data used during process execution, enabling efficient data manipulation during execution. Then, designing process contracts is an important step that defines user roles, data validation rules, and other aspects related to data input and usage in the business process. This solution provides 6 BDM objects representing documents generated during process execution. For each of these objects, a corresponding business variable is created to facilitate working with real data. The values of these business variables are set through the definition of process contracts, which are specifically tailored for each task to enable efficient data manipulation during process execution. Each mentioned contract is paired with a corresponding form created using UI Designer.

Following the basic steps in creating a Bonita BPM application, defining the actors in the process, who are crucial for its proper functioning, comes next. Within the process diagram, for all tasks that require human resources, it is necessary to clearly define actors for each swimlane. These actors are responsible for executing tasks grouped within their lane. In the process of preparing for deployment, actors are mapped to specific employees, groups of employees, roles within the organization, or the entire organization, a process known as "actor mapping". For this process, six key actors are defined: Customer, Salesperson, Production Manager, Production Operators, Quality Engineer, and Warehouse Manager. Each of these actors has specific tasks and permissions, which allows for efficient and organized process management.

In continuation, the functioning of the production planning process within the organization is detailed, starting from the submission of a purchase order request by the client to the final inspection and resource management. The production process begins when the client submits a purchase order request, which serves as the initiator of the entire process. Subsequently, the purchase order request is forwarded to the sales department, which reviews and verifies the request. If the verification is unsuccessful, the purchase order request is rejected. Otherwise, the approved order triggers the generation of an operational plan by the production director. Once the operational plan is created, the availability of materials and tools is checked. If the necessary resources are not available, the sales department is responsible for ordering them. On the other hand, if all the necessary resources are available, the generation of documents for production planning begins, including work orders, technological procedures, route lists, material specifications, and records of receipt and delivery. Based on these documents, the production department will carry out product development using the appropriate production technology and performing manufacturing operations. After all manufacturing operations are completed, the quality department conducts quality control of the products. If the quality is unsatisfactory, the production process returns to verifying the availability of materials and tools, and the subsequent steps are repeated. If the final product inspection is satisfactory, it is necessary for the warehouse to create a return document for all unused resources during the production process. In this way, the production planning process is successfully concluded.

In addition to designing the application, it is essential to create a homepage that visualizes order data as the final step in developing the conceptual solution. This way, the application can be used regardless of whether a process instance is created. With this step, the development of the proposed solution is concluded, and it can be tested through the Bonita portal.

5. PROPOSED SOLUTION

This section elaborates on the automation of the production planning process, underscoring the significance of production documents. The proposed conceptual solution uses Bonita software to augment operational efficiency by streamlining the production planning process. The proposed solution aims to enhance the production planning process, leading to improved efficiency and productivity.

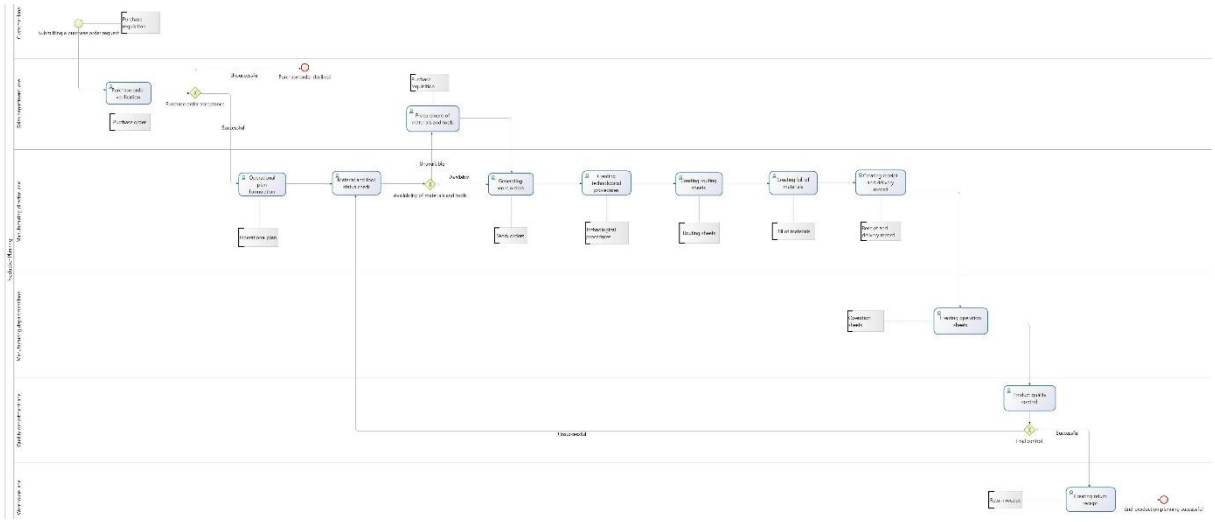

Figure 1. Production planning process diagram

Upon analyzing the production system in question, the foremost impediment that came to light was the circulation of production planning documents in paper form. Moreover, the production planning process itself was found to be inadequately organized and inefficient.The production planning process results in generating a significant volume of documentation and paperwork. Ensuring the reliability of this data, as well as its storage and monitoring procedures, is essential. Furthermore, promoting seamless communication and collaboration among diverse departments within the company remains imperative.

Bonita can empower manufacturing companies to achieve technological advancements and enhance business modernization, ultimately positioning them competitively in the market. It also reduces mundane and manual work, considering that it automates production planning and turns documentation into paperless form. In addition to the aforementioned benefits, it's worth emphasizing that Bonita amplifies visibility into the production planning workflow, enabling more effective process monitoring and control.

6. CONCLUSION

This paper highlights the importance of automating the production planning process and utilizing a BPM tool called Bonita. Through a review of relevant research displayed throughout the paper, the crucial role of BPM and BPMS is emphasized, particularly in the flow of production documents. The main objective of this study was to propose a solution for inefficient documentation flow and production planning processes.

Identification of key production planning processes and documentation for automation was conducted to understand the essential elements for implementing the proposed solution. The methodology for developing the solution, focusing on Bonita software in production planning, was elaborated in detail.

The proposed conceptual solution, depicted through a process diagram, illustrates the benefits of automating production planning processes: improved efficiency, and speed in handling production documentation, contributing to operational excellence and process monitoring.

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EVALUATION OF CIRCULAR ECONOMY INDICATORS IN EU COUNTRIES

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Abstract: Circular economy principles are proposed to solve problems of various topics, such as waste reduction, prevention of pollution and climate change, conservation of resources and security of their supply, economic resilience, therefore it is important not only to follow them, but also to properly assess their impact, so that interested parties could make informed decisions and develop effective strategies to promote circular economy principles and practices. However, as can be seen in the scientific literature, despite the abundance of literature that discusses circular economy evaluation indicators, the comprehensiveness of circular economy evaluation is missing. Thus formulating a scientific problem: What indicators can be used to assess the level of the circular economy in countries?
The purpose of the research. After analyzing the theoretical aspects of the evaluation of the circular economy, to assess the level of the circular economy in the EU countries. *Research methods* include comparative and systematic analysis of scientific literature, Entropy method.

Keywords: circular economy, EU, indicators, Entropy weighting method.

1. INTRODUCTION

Relevance of the topic. After the European Parliament (hereinafter - the EP) approved the European climate legislation in 2021, in which, in order to implement the Paris Agreement, drawn up under the United Nations General Convention on Climate Change and to enact the 2019 obligations set out in the Commission's communication "The European Green Deal" (hereinafter - the European Green Deal) – it is important to "reorganize the Union so that its society is just and prosperous, so that it is characterized by a modern, resource-efficient and competitive economy in which by 2050 net emissions of greenhouse gases (GHG) would be zero, and economic growth would be decoupled from the use of resources" (European Green Deal, 2019); more and more attention is paid to the implementation of the green transformation of the European Union (hereinafter - EU) countries. There is no doubt that the principles of the circular economy, on the basis of which it is possible to solve the economic, social and environmental challenges we face in today's society, become very important in this context.

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The European Commission, in order to accelerate the transition to a circular economy, in 2022 presented the new circular economy action plan, and in 2023 The EP approved legislation that should ensure the movement towards a circular economy. Circular economy principles are proposed to solve problems of various topics, such as waste reduction, prevention of pollution and climate change, conservation of resources and security of their supply, economic resilience, therefore it is important not only to follow them, but also to properly assess their impact, so that interested parties could make informed decisions and develop effective strategies to promote circular economy principles and practices. However, as noted by Musyarofah et al. (2023), despite the wealth of literature discussing circular economy assessment indicators, the comprehensiveness of circular economy assessment is lacking (Musyarofah et al., 2023). The fact that the evaluation of the circular economy has been improved is also emphasized by the European Court of Auditors, in the presented special report in 2023, no. 17 (European Court of Auditors, 2023).

Scientific research problem. What indicators can be used to assess the level of the circular economy in countries?

The purpose of the article. After analyzing the theoretical aspects of circular economy evaluation, to assess the level of circular economy in EU countries.

Research methods: analysis, systematization and generalization of scientific literature, Entropy weighting method.

2. CIRCULAR ECONOMY INDICATORS

In order to achieve the goal of the research, it is necessary to identify, based on which indicators, it is possible to comprehensively assess the situation of the circular economy in the country. Xijie & Jin (2023) state that the topic of the circular economy is analyzed by many countries, but "so far there is no single indicator that comprehensively measures the level of the circular economy" (Xijie & Jin, 2023). The fact that the situation of the circular economy, at various levels, is assessed by including different indicators in the analysis is also proven by the OECD (2021). The OECD has identified as many as 474 indicators related to the circular economy in the analyzed period (2018-2020), which reflect the progress of the circular economy. The collected indicators belong to 29 circular economy studies, of which 8 are applied at the national level, 8 at the regional level and 11 at the local level (OECD, 2021). Saidani et al. (2019) point out that “academics, industrialists and policy makers around the world agree on the need to use circular economy metrics to manage the transition towards a circular economy at various systemic levels” (Saidani et. al., 2019). However, the research conducted by scientists is another proof that the world is missing a unified system for evaluating the circular economy. The researchers, after reviewing the literature, identified 55 sets of indicators developed by researchers, consulting firms and government agencies.

EAA (2024) emphasizes that circular economy goals should be directed not only to waste recycling, but also to other areas, and the result of those actions should be measurable. According to the agency, "to support the new circular economy goals, a reliable and responsive monitoring system is needed at all levels, from EU-wide statistics to sectoral datasets." (European Environment Agency, 2024).

The United Nations Organization (hereinafter - UNO) (2024) presents the main principles that must be followed to select circular indicators for monitoring the economy, namely the importance and utility of policies for consumers, analytical reliability and measurability. The UNO emphasizes that "indicators that best reflect the main trends related to the transition to a circular economy must be carefully selected, as the number of potentially

useful indicators can be large, and it is necessary to apply commonly agreed ones that validate their selection (United Nations Economic Commission for Europe, 2024).

EAA (2024) sets out a reliable, freely available, quality-assuring circular economy monitoring framework (Circular Economy Monitoring Framework - CEMF), which in 2023 supplemented with new indicators in order to better reflect the problems solved by the circular economy. Monitoring indicators presented in Table 1.

Table 1. Circular economy monitoring system (Eurostat, 2023)

Subject area	Validity	Indicators
Production and consumption	Decreasing consumption of materials means that economic growth is decoupled from resource use.	Productivity of resources Consumption of raw materials Green public procurement
Generation of waste	In a circular economy, the generation of waste is reduced to a minimum.	The total amount of generated waste per inhabitant The ratio of the total amount of generated waste (excluding large mineral waste) to GDP Amount of generated municipal waste per inhabitant Food waste Amount of packaging waste generated per inhabitant Amount of plastic packaging waste generated per inhabitant
Waste management	Increasing recycling is part of the transition to a circular economy.	Municipal waste recycling rate Recycling rate for all wastes, except for bulky mineral waste Waste recycling rate for all packaging Plastic packaging waste recycling rate Recycling rate for separately collected electrical and electronic equipment
Secondary materials	In a circular economy, secondary raw materials are usually used to make new products.	Circular use of materials Proportion of materials that can be recycled at the end of their life cycle
Trade in raw materials suitable for processing	Trade in recyclable raw materials demonstrates the importance of the internal market and participation in the circular economy at the global level.	Import from non-EU countries Export to non-EU countries EU internal trade
Competitiveness and innovation	A circular economy can help create jobs and boost economic growth.	Private investments Employment
Green innovations	Innovative technologies related to the circular economy increase the EU's.	Patents related to waste management and recycling
Global sustainability	The circular economy helps ensure climate neutrality.	GHG emissions are emitted during production activities Usage footprint
Resistance	The circular economy contributes to the security of the supply of raw materials and helps to reduce the risks associated with the supply, especially of the most important raw materials.	Dependence on the import of raw materials EU supply of raw materials (%)

As we can see in Table 1, each criterion of the circular economy is evaluated by the corresponding indicators, the positive/negative change of which reflects the progress/non-progress of the circular economy. The EEA (2024) states that the new monitoring framework includes a broader assessment of the circular economy, where more attention is paid not only to waste recycling, but also to the economic production side, the material and consumption footprint, the global aspect of sustainability, neutrality and resilience (European Environment Agency, 2024). However, the analysis of single indicators would allow to evaluate only the dynamics during the analyzed period or to compare the analyzed units, according to only that specific analyzed criterion, therefore, in order to comprehensively assess the level of the circular economy in countries, in the following work, a circular economy assessment methodology is created, when it includes multi-criteria assessment methods (MCDA).

3. DATA AND METHODOLOGY

3.1. Entropy method

In order to determine the weights of different criteria, one of the most commonly used methods is the entropy weighting method. According to Qu et. al. (2022), "the method is widely used in comprehensive assessment available that use different assessment indices" (Qu et. al., 2022). Podvezko & Podviezko (2014) emphasize that the entropy weight increase is linked to the degree of dominance of one criterion value among all alternatives, and although "multifactor regression models and other ideas can also be applied, the objective method of entropy is the most commonly used method for determining objective weights" (Podvezko & Podviezko, 2014). Jin et al. al. (2020) provide systematic steps for using the entropy method, which are based on research:

1. Matrix values are normalized according to the formulas, depending on the direction (maximizing (1) or minimizing (2)):

$$\tilde{X}_{ij} = \frac{X_{ij} - minX_{ij}}{max\ X_{ij} - minX_{ij}} \quad (1)$$

$$\tilde{X}_{ij} = \frac{maxX_{ij} - X_{ij}}{max\ X_{ij} - minX_{ij}} \quad (2)$$

where $\tilde{X}$ means the normalized value of one of the analyzed alternatives from 0 to 1 without dimension.

2. The entropy value of each individual indicator is calculated:

$$k = 1/\ln(n) \quad (3)$$

$$H_j = -k \sum_{i=1}^{m} X_{ij}\, lnX_{ij} \quad (4)$$

3. The information utility value (level of change, non-normalized values of entropy weights) (d_j) and criterion weight ω_j (entropy weight, normalized values of calculated d_j) are calculated for each indicator:

$$d_j = 1 - H_j \quad (5)$$

$$\omega_j = \frac{d_j}{\sum_{j=1}^{n} d_j} = \frac{1-H_j}{\sum_{j=1}^{n}(1-H_j)} \quad (6)$$

where, criterion weights range from 0 till 1, $0 \leq \omega_j \leq 1 \sum \omega_j = 1$ (Podvezko & Podviezko, 2014; Jin et al., 2020).

3.2. Indicator justification

The evaluation of the circular economy in the EU countries will be carried out, including the indicators most often identified in the scientific literature and systematized by the European Commission, which reflect the situation of the circular economy in the country, according to the following evaluation criteria - production and consumption, generation and management of waste, development of markets for secondary raw materials, trade in raw materials suitable for recycling, competitiveness and innovation, sustainability and resilience. The table shows the indicators that are included in the analysis and information about them (see Table 2).

Table 2. Indicators used in the study (European Commission, 2023)

Subject area	Validity	Indicator	Marking	Unit of measurement
Production and consumption	In order to measure economic growth decoupled from resource use, reflected by declining material consumption	Consumption of raw materials (material footprint) Resource productivity	MF	tons/capita
			RP	index
Formation of waste	In order to measure the decrease/increase in waste generation, where decrease means progress and increase negative progress in the circular economy	Waste generation per capital	WG	kg/inhabitant
Waste management	In order to estimate the amount of waste recycling, where increasing amounts mean the transition towards a circular economy	Recycling rate of all waste excluding major mineral waste	RR	percent
Secondary materials	In order to appreciate, the development of secondary raw materials markets, with the growing use of circular materials, represents progress in the circular economy.	Circular material use rate	CMUR	percent
Trade in recyclable materials	In order to assess trade volumes that reflect the importance of the internal market and participation in the circular economy at the global level.	Intra EU trade	IINT	tons
Competitiveness and innovation	To measure progress in investment and employment sectors where circular economy solutions contribute to economic growth	Private investment (in circular economy sectors) (private investments) Employment (in circular economy sectors) (persons employed)	PI	percent from GDP, at prices

			PE	percent from employment
Green innovation	In order to assess how many innovative technologies are created that increase the EU's competitiveness in the world.	Patents related to waste management and recycling	PA	number
Global sustainability	In order to assess how much the climate impact is reduced/increased, where the decreasing amount means towards climate neutrality	GHG emissions from production activities	GG	kg/inhabitant
Resilience	In order to assess supply-side risks, a higher percentage means a greater dependence on essential raw materials.	Material import dependency	MD	percent

As we can see in Table 2, the European Commission (2023), in order to assess the progress of the circular economy in the countries, presents structured indicators that, according to the authors, create an evaluation system that is "based on existing official statistics from Eurostat and other official sources, the system does not increase the administrative burden, and the selected indicators were evaluated in terms of their suitability, acceptability, reliability, ease and robustness" (European Commission, 2023).

4. RESULTS AND DISCUSSION

First, the criteria weights used in the study were calculated using the Entropy method. The values of all analyzed criteria were normalized after determining whether the criterion is maximizing or minimizing, using the appropriate formulas described in the methodology section. Whether the weights are calculated correctly is checked by adding them up. The values of the calculated weights are presented in the table (see Table 3).

Table 3. Criteria weights based on the Entropy method (created by the authors)

CRITERION	**WEIGHT**
Raw Material Consumption (MF)	0.03161
Resource Productivity (RP)	0.06836
Waste Generation (WG)	0.11531
Rubbish recycling (RR)	0.02804
Circular use of materials (CMUR)	0.08319
EU internal trade (IIN)	0.23899
Private investments (in circular economy sectors) (PI)	0.03905
Employment in circular economy sectors (PE)	0.02333
Patents related to waste management and recycling (PA)	030952
GHG emissions are emitted during production activities (GG)	0.02124
Dependence on the import of raw materials	0.04136
SUM	1

As we can see in Table 3, the highest weights, based on the calculations of the Entropy method, are assigned to the number of patents related to waste management and recycling (0.30952), the amount of imported waste recycled within the EU (0.23899) and the amount of waste generation in the country (0.11531). , and the lowest weights are assigned to the amount of greenhouse gases emitted during production activities (0.02124) and employment in circular economy sectors (0.02333). The values of weights for other criteria range from 0.005319 to 0.02804. It is important to emphasize that all the criteria included in the analysis are significant in assessing the situation of the circular economy in the country, but their significance is different, therefore, in order to assess the significance of the criteria, the objective method of

Entropy, which is usually applied in practice, where the increase in the Entropy weight is linked to the degree of dominance of one criterion value among of all alternatives" (Podvezko & Podviezko, 2014). Data analyzed for 2020.

5. CONCLUSION

Based on the objectives of the circular economy, which also includes proper waste management, which is the most mature aspect of the circular economy, reflecting long-term policies aimed at improving waste management, and other aspects such as value retention and production, climate change and pollution prevention, secondary raw materials markets development, innovations, it was found that it is important to include indicators in the analysis that reflect the situation from the point of view of the mentioned aspects. The following indicators are used in the study - indicators of raw material consumption, resource productivity, waste generation and processing, circular use of materials, intra-EU trade, investment, employment, patents, GHG quantity and dependence on raw material imports. After applying the Entropy method, the highest weights were determined for the following criteria - the number of patents related to waste management and recycling (0.30952), then the amount of imported waste recycled within the EU (0.23899) and the amount of waste generated in the country (0.11531), while the lowest weights are attributed to the amount of greenhouse gases emitted during production activities (0.02124) and employment in circular economy sectors (0.02333).

Based on the data obtained during the Entropy method and determining the weights for different criteria, it can be stated that the greatest importance in the circular economy in the EU countries is technological innovation and cross-border waste management. These data show that innovation in the field of waste management and recycling (as shown by the number of patents) and efficient movement and recycling of waste within the EU are very important factors contributing to the development of the circular economy. The low weights assigned to greenhouse gas emissions during production and employment in the circular economy sectors indicate that these criteria, although important for environmental and social aspects, currently have less influence on the overall efficiency of the circular economy, according to the measurement criteria set.

The conclusion would be that the current focus should be on promoting technological innovation and making cross-border waste recycling processes more efficient in order to further strengthen the development of the circular economy. This shows that these aspects are currently the most valued when it comes to sustainability and resource efficiency.

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Appendix 1

Entropy method application calculations

	Normalized values										
Country	MF	RP	WG	RR	CMUR	IMPORTINTRA	PI	PE	PA	GG	MD
Belgium	0.0262	0.0624	0.0361	0.0480	0.0874	0.1260	0.0792	0.0264	0.0266	0.0388	0.0687
Bulgaria	0.0417	0.0071	0.1027	0.0329	0.0224	0.0059	0.0347	0.0305	0.0000	0.0355	0.0152
Czech republic	0.0326	0.0234	0.0220	0.0378	0.0437	0.0245	0.0198	0.0467	0.0347	0.0455	0.0296
Denmark	0.0516	0.0432	0.0211	0.0420	0.0289	0.0196	0.0396	0.0244	0.0137	0.0662	0.0352
Germany	0.0304	0.0544	0.0295	0.0656	0.0490	0.1922	0.0396	0.0346	0.2211	0.0380	0.0377
Estonia	0.0583	0.0135	0.0744	0.0270	0.0627	0.0036	0.0347	0.0447	0.0000	0.0430	0.0254
Ireland	0.0206	0.0663	0.0199	0.0381	0.0065	0.0096	0.0248	0.0305	0.0185	0.0565	0.0302
Greece	0.0231	0.0311	0.0162	0.0169	0.0160	0.0063	0.0099	0.0264	0.0024	0.0386	0.0380
Spain	0.0203	0.0498	0.0136	0.0363	0.0350	0.0693	0.0248	0.0467	0.1033	0.0246	0.0357
France	0.0256	0.0615	0.0281	0.0389	0.0710	0.0877	0.0396	0.0366	0.1312	0.0251	0.0344
Croatia	0.0264	0.0213	0.0091	0.0275	0.0209	0.0105	0.0297	0.0610	0.0000	0.0242	0.0321
Italy	0.0206	0.0694	0.0180	0.0480	0.0783	0.0863	0.0446	0.0508	0.1041	0.0268	0.0442
Cyprus	0.0465	0.0268	0.0152	0.0159	0.0144	0.0009	0.0149	0.0386	0.0000	0.0415	0.0308
Latvia	0.0363	0.0195	0.0092	0.0371	0.0198	0.0057	0.0545	0.0549	0.0024	0.0267	0.0304
Lithuania	0.0441	0.0157	0.0147	0.0423	0.0152	0.0089	0.0347	0.0569	0.0000	0.0435	0.0349
Luxemburgh	0.0498	0.0849	0.0895	0.0493	0.0365	0.0380	0.0644	0.0081	0.0121	0.0705	0.0859
Hungary	0.0295	0.0185	0.0108	0.0299	0.0198	0.0174	0.0396	0.0467	0.0000	0.0278	0.0255
Malta	0.0273	0.0372	0.0419	0.0102	0.0627	0.0003	0.0495	0.0386	0.0000	0.0198	0.0659
Nytherlands	0.0165	0.0868	0.0439	0.0531	0.1033	0.1202	0.0545	0.0224	0.0641	0.0473	0.0771
Austria	0.0408	0.0443	0.0473	0.0582	0.0437	0.0567	0.0693	0.0224	0.0314	0.0325	0.0421
Poland	0.0363	0.0155	0.0275	0.0361	0.0277	0.0352	0.0396	0.0549	0.0835	0.0477	0.0183
Portugal	0.0315	0.0243	0.0099	0.0250	0.0095	0.0206	0.0495	0.0366	0.0262	0.0260	0.0289
Romania	0.0613	0.0068	0.0449	0.0111	0.0057	0.0093	0.0248	0.0203	0.0242	0.0264	0.0087
Slovenia	0.0341	0.0320	0.0219	0.0554	0.0376	0.0143	0.0248	0.0305	0.0048	0.0336	0.0439
Slovakia	0.0268	0.0271	0.0143	0.0423	0.0395	0.0137	0.0248	0.0427	0.0000	0.0304	0.0406
Finland	0.0918	0.0182	0.1285	0.0393	0.0167	0.0064	0.0149	0.0325	0.0726	0.0427	0.0179
Sweden	0.0500	0.0390	0.0897	0.0358	0.0262	0.0109	0.0198	0.0346	0.0229	0.0211	0.0225

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The meaning of Entropy											
Country	MF	RP	WG	RR	CMUR	IMPORTINTRA	PI	PE	PA	GG	MD
Belgium	-0.095	-0.173	-0.120	-0.146	-0.213	-0.261	-0.201	-0.096	-0.096	-0.126	-0.184
Bulgaria	-0.133	-0.035	-0.234	-0.112	-0.085	-0.030	-0.117	-0.106	0.000	-0.118	-0.064
Czech republic	-0.111	-0.088	-0.084	-0.124	-0.137	-0.091	-0.078	-0.143	-0.117	-0.141	-0.104
Denmark	-0.153	-0.136	-0.082	-0.133	-0.102	-0.077	-0.128	-0.091	-0.059	-0.180	-0.118
Germany	-0.106	-0.158	-0.104	-0.179	-0.148	-0.317	-0.128	-0.116	-0.334	-0.124	-0.124
Estonia	-0.166	-0.058	-0.193	-0.097	-0.174	-0.020	-0.117	-0.139	0.000	-0.135	-0.093
Ireland	-0.080	-0.180	-0.078	-0.124	-0.033	-0.045	-0.092	-0.106	-0.074	-0.162	-0.106
Greece	-0.087	-0.108	-0.067	-0.069	-0.066	-0.032	-0.046	-0.096	-0.015	-0.126	-0.124
Spain	-0.079	-0.149	-0.059	-0.120	-0.117	-0.185	-0.092	-0.143	-0.235	-0.091	-0.119
France	-0.094	-0.171	-0.100	-0.126	-0.188	-0.213	-0.128	-0.121	-0.266	-0.092	-0.116
Croatia	-0.096	-0.082	-0.043	-0.099	-0.081	-0.048	-0.104	-0.171	0.000	-0.090	-0.110
Italy	-0.080	-0.185	-0.072	-0.146	-0.199	-0.211	-0.139	-0.151	-0.236	-0.097	-0.138
Cyprus	-0.143	-0.097	-0.064	-0.066	-0.061	-0.006	-0.063	-0.126	0.000	-0.132	-0.107
Latvia	-0.120	-0.077	-0043	-0.122	-0.078	-0.029	-0.158	-0.159	-0.015	-0.097	-0.106
Lithuania	-0.138	-0.065	-0.062	-0.134	-0.064	-0.042	-0.117	-0.163	0.000	-0.136	-0.117
Luxemburgh	-0.149	-0.209	-0.216	-0.148	-0.121	-0.124	-0.177	-0.039	-0.053	-0.187	-0,211
Hungary	-0.104	-0.074	-0.049	-0.105	-0.078	-0.070	-0.128	-0.143	0.000	-0.099	-0,094
Malta	-0.098	-0.122	-0.133	-0.047	-0.174	-0.002	-0.149	-0.126	0.000	-0.078	-0,179
Nytherlands	-0.068	-0.212	-0.137	-0.156	-0.235	-0.255	-0.158	-0.085	-0.176	-0.144	-0,198
Austria	-0.131	-0.138	-0.144	-0.165	-0.137	-0.163	-0.185	-0.085	-0.109	-0.111	-0,133
Poland	-0.120	-0.065	-0.099	-0.120	-0.099	-0.118	-0.128	-0.159	-0.207	-0.145	-0.073
Portugal	-0.109	-0.090	-0.046	-0.092	-0.044	-0.080	-0.149	-0.121	-0.096	-0.095	-0.102
Romania	-0.171	-0.034	-0.139	-0.050	-0.029	-0.044	-0.092	-0.079	-0.090	-0.096	-0.041
Slovenia	-0.115	-0.110	-0.084	-0.160	-0.123	-0.061	-0.092	-0.106	-0.026	-0.114	-0.137
Slovakia	-0.097	-0.098	-0.061	-0.134	-0.128	-0.059	-0.092	-0.135	0.000	-0.106	-0.130
Finland	-0.219	-0.073	-0.264	-0.127	-0.068	-0.032	-0.063	-0.111	-0.190	-0.135	-0.072
Sweden	-0.150	-0.127	-0.216	-0.119	-0.095	-0.049	-0.078	-0.116	-0.086	-0.082	-0.085
Sum	-3.212	-3.115	-2.992	-3.222	-3.076	-2.665	-3.193	-3.234	-2.479	-3.240	-3.187
Entropy value	0.975	0.945	0.908	0.978	0.933	0.809	0.969	0.981	0.752	0.983	0.967
Level of variation	0.025	0.055	0.092	0.022	0.067	0.191	0.031	0.019	0.248	0.017	0.033
Change level amount	0.801										
Weight	0.032	0.068	0.115	0.028	0.083	0.239	0.039	0.023	0.310	0.021	0.041

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THE IMPACT OF EXECUTIVE COACHING ON THE INNOVATION PERFORMANCE OF EMPLOYEES

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Abstract: The purpose of this paper is analysis and assessment of the impact of executive coaching on organizational performance, through research and correlation with innovations. The initiative for the paper arose from the need for additional research in this area, in relation to the literature research and additional research on the situation in N. Macedonia, in order to determine the impact of executive coaching on innovation performance in organizations. The focus of this paper revolves around these questions: Is coaching related to innovation? What and to what measure do companies know about and apply coaching as a tool for innovation? How much does executive coaching or top management coaching contribute to the innovation performance of managers, employees, and the organization as a whole? Multiple perspectives on executive coaching and innovation are covered throughout the paper, starting with a positive correlation between coaching and innovation performance. The research in this direction pointed to the fact that in our country, coaching as a scientific discipline is being introduced slowly. It gives results, however, regarding the theoretical and practical applicability more scientific studies and research are needed to show its impact on personal and organizational aspects and development.

Keywords: innovation, coaching influence, executive coaching, organizational performance

1. THE CONNECTION BETWEEN EXECUTIVE COACHING AND ORGANIZATIONAL INNOVATION PERFORMANCE: THEORETICAL FRAMEWORK

The success and continuity of an organization in dynamic and volatile conditions prevailing today largely depends on its ability to respond to changes and the ability to innovate. In order to ensure competitive advantage and sustainability in the market, the organization needs to build innovation capabilities, and for that, sustainable innovation performance is required. A group of scientists in 2021 (Roša & Lace 2021) conducted research in this context and concluded that in order to achieve sustainable performance, the organization should build technical and innovative capabilities with practices that support innovation processes. In this

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context, and with regard to the innovative performance of organizations, coaching is regarded as a process that is facilitating learning of individuals, deepening their knowledge, in order to achieve goals, by discovering their potential and increasing awareness of new opportunities (Roša & Lace 2021). For the needs of an organization, coaching is mostly used for top management, leadership development and human resources development. In the scientific literature, there is already confirmed evidence of the impact of coaching, especially executive coaching, on the development of leadership skills, which contribute to the organizations being directed towards building a climate for continuous innovation of processes, services, and products. The group of scientists in the same research determined through the obtained results that executive coaching, or top management coaching has a greater effect than training and courses in terms of innovative performance in the organization. In this paper, we will delve further into the impact of executive coaching on organizational performance and the cultivation of innovation, positing that such impacts are significantly influenced by coaching interactions. **The evolution of coaching:** The concept of coaching in the business realm gained prominence in the 1920s, primarily in the United States and Western Europe. This emergence coincided with a period of intense managerial stress induced by economic downturns, prompting the necessity for a developmental tool to enhance individual performance and organizational progress. Consequently, a surge in organization-specific training and development initiatives occurred, shedding light on the efficacy of personalized approaches to personal growth. Although the term "coaching" first appeared in scientific literature in 1937, its significance has undergone a transformative resurgence in the past two decades. Analysis of research within this discipline indicates that coaching plays a pivotal role in modern management practices (Malesevic, 2011). **The etymology of "coach":** The term "coach" traces its origins back to the 15th century, deriving from the Hungarian village of Kocs, where coaches were initially crafted as efficient modes of transportation. Analogously, coaching serves as a means to transport individuals from one point to another, metaphorically representing progress or development. The earliest academic usage of "coach" dates back to the 1830s at Oxford University, where it denoted a professor-tutor assisting students in their academic endeavors. The informal connotation of "coach" implied a facilitative role, akin to guiding a student from point A to point B—a concept reminiscent of the literal transportation provided by a carriage (Underhill et al., 2007). **Definition and essence of coaching**: Within the business context, coaching embodies a form of supportive guidance akin to teaching. The coach, serving as the supportive entity, aids the client in their developmental journey. Various definitions of coaching exist, yet they converge around the International Coaching Federation's (ICF) characterization of coaching as a collaborative partnership aimed at fostering creative thinking and maximizing personal and professional potential. Through a series of questions, methods, strategies, and techniques, the coach assists the client in uncovering latent potentials and resources. This process typically unfolds through individual coaching sessions, although team and organizational coaching modalities also exist. Numerous authors have endeavored to classify coaching types based on approaches or target groups. Athanasopoulou and Dopson (2015) proposed a classification which includes "academic coaching, professional coaching, development coaching, management coaching, financial coaching, group coaching, health coaching, high potential coaching, knowledge coaching, leadership coaching, legal coaching, managerial training (where managers act as coaches), performance coaching, personal or life coaching, project management coaching, results coaching, feedback coaching, sports coaching, transactional coaching, and transformational coaching, among others."

Executive coaching, situated at the apex of business coaching, targets individuals within organizations who wield significant authority. It is often characterized as coaching for solitary decision-makers expected to possess all answers. However, reducing executive coaching to

mere conversational skill belies its depth and complexity. Effective executive coaching necessitates both profound experiential knowledge and methodological rigor. It entails a delicate balance between artistry and scientific inquiry.Essentially, executive coaching entails a supportive relationship between a client (typically a high-level manager) and a coach, employing diverse techniques to achieve jointly defined objectives. These goals revolve around enhancing professional growth, personal satisfaction, and organizational effectiveness within the confines of a formal coaching contract. Executive coaching, as described in literature, constitutes a short to medium-term intervention focused on competency development. It involves face-to-face sessions aimed at bolstering self-awareness through active learning methods (Dembkowsky et al., 2006). While executive coaching is not a recent phenomenon, its popularity has surged in recent years due to organizational shifts such as expansion, downsizing, and rapid evolution, which demand proactive leadership preparation. There is growing recognition of the role of preventive leadership development in averting crises. Although numerous studies explore the impact of executive coaching on leadership competencies, empirical evidence remains insufficient. While practical experiences abound, further scientific inquiry is needed to comprehensively understand the outcomes and effects of executive coaching (Levinson,1996).

2. THE IMPACT IF EXECUTIVE COACHING ON THEN INOVATION PERFORMANCE OF ORGANIZATIONS

When discussing executive coaching, it's important to highlight its three primary lines of action (Underhill et al., 2007):

- Development of Skills: Executive coaching often focuses on enhancing interpersonal or leadership skills essential for effective management within organizations.
- Performance Enhancement: Executive coaching assists individuals in navigating through changes, new challenges, and innovation initiatives, thereby optimizing performance outcomes.
- Future Development: Executive coaching equips individuals with the necessary competencies and insights required to thrive in future professional environments.

As the landscape of business continues to evolve, coaching emerges as an indispensable tool in the arsenal of developmental practices. Its influence reverberates not only within the confines of individual interactions but also permeates throughout entire organizations, shaping behaviors and enhancing productivity. Within this dynamic framework, coaching serves as a conduit for transformative change, catalyzing tangible improvements in individual performance that cascade into broader organizational shifts.Central to the efficacy of coaching is its capacity to nurture self-awareness and self-directed learning. Through probing inquiries and tailored guidance, coaches empower individuals to explore their innermost motivations, refine their skill sets, and broaden their perspectives. This heightened self-awareness becomes a cornerstone for enhanced decision-making abilities, empowering individuals to navigate complex challenges with confidence and clarity (Yuping, 2021).

Across the expanse of scientific literature, a resounding chorus underscores the profound impact of coaching on critical developmental facets such as management, leadership, and human resources. With each coaching interaction, organizations witness not just incremental growth, but a holistic transformation that extends to the very core of their operational ethos. Moreover, coaching serves as a crucible for fostering entrepreneurial acumen and cultivating a culture of innovation—an indispensable asset in today's rapidly evolving business landscape. Empirical studies, such as the seminal research conducted in Finland in

2013 by Hussinki, Henri, Kianto, Aino, and Vanhala, shed light on the intricate interplay between knowledge-based issues and organizational innovation performance (Hussinki et al., 2015). Here, the prescription for bolstering innovation performance is clear: strategic management, continuous competence development, equitable knowledge compensation practices, and judicious utilization of information technology. These insights serve as guideposts for organizations seeking to harness the full potential of their innovation endeavors. At the forefront of this transformative journey lies executive coaching—a linchpin in the realm of knowledge management and innovation catalysis. Beyond its role in day-to-day operations, executive coaching serves as a vanguard for ushering in a culture of innovation excellence. Its impact reverberates across organizational hierarchies, permeating every facet of the enterprise with a spirit of creativity and forward-thinking vision. In essence, coaching emerges not merely as a developmental practice, but as a lodestar guiding organizations towards a future defined by ingenuity, resilience, and sustained innovation. As organizations navigate the complexities of an ever-evolving marketplace, the role of coaching assumes heightened significance, offering a compass for charting a course towards sustained success and organizational flourishing.

In the dynamic landscape of modern organizations, the ability to sustain and foster innovation is paramount to maintaining competitive advantage. Today, businesses of all sizes, from multinational corporations to small and medium enterprises, are deeply engaged in the process of open innovation. Managers are continuously exploring new tools, methods, strategies, and work techniques to enhance employee performance and drive innovation within their organizations. In this context, innovation has become not just a measure of progress but a standard for organizational development.Crucially, individual innovation performance among employees is directly influenced by leadership style. Studies by researchers such as Spivak (2020) and Holovchuk (2017) emphasize the essential role of leaders in initiating innovative changes within organizations. They highlight the leader's responsibility to motivate and inspire followers, steering them towards defined goals while accommodating diverse perspectives. In the evolving landscape of organizational leadership, informal leadership models are gaining prominence. Futurists like Ferrazzi (2022) predict a shift towards autonomous teams in the coming years, with trust in leaders and collaborative teamwork emerging as key drivers of success.

Amid the challenges posed by the Covid-19 pandemic and subsequent crises, organizational development demands innovative approaches. Researchers stress the need for leaders to adapt to evolving circumstances and drive organizational change effectively. Executive coaching has emerged as a pivotal tool for developing leadership competencies, navigating organizational transitions, and enhancing innovation performance. Recent studies by Krasovska, Stadnyk and Khomych (Karasovska et al., 2022) propose a motivational model of leadership that emphasizes the leader's role in aligning goals with personal employee motives and selecting appropriate means to achieve them. Looking ahead to the post-pandemic era and anticipated global recovery efforts, organizations must embrace new business models to gain competitive advantages. Innovation performance, catalyzed by effective leadership, will play a central role in shaping these models. Research by Hemeiri and others underscores the importance of leadership in encouraging employees to push beyond conventional boundaries (Hemeiri et al., 2021). Their studies explore how coaching leadership fosters skill development and strategic decision-making, ultimately enhancing employee satisfaction and collaboration. From a managerial perspective, Warrick (2017) emphasizes the critical need for leaders who can navigate today's rapidly changing and competitive landscape. Effective leaders, characterized by predictability, openness, and adeptness in fostering high-performance organizational cultures, are essential for driving innovation and sustaining competitiveness in the modern business environment.

3. ANALYSIS AND INTERPRETATION OF RESULTS

In order to see if there is a difference in the influence of managers/leaders after a completed coaching process on the innovative performance of employees, a $\chi 2$ test was performed with a significance level of 0.05. The relationship between the influence of different variables and subvariables was analyzed with Pearson's correlation, while cases with a significance level of 0.01 ($p<0.01$) were considered significant. To confirm the Pearson correlation results, an independent samples χ 2 test was performed with a significance level of 0.05. All statistical analyzes were performed using SPSS statistical software. According to the position in the organization, the research included 22 managers/leaders and 111 employees from the same organizations, which means that the number of respondents is 133 in total. According to the number of employees out of 133 respondents, 23 are in micro organizations, 63 in small, 38 of them in medium organizations and 9 respondents in large organizations with over 250 employees.Regarding the leadership style and how it affects the innovative performance of the employees, we obtained the following results: Most of the employees declared themselves as fully agreed (50.5%) and 40.9% of the managers declared themselves as fully agreed. 24.3% of employees and 50% of managers partially agree. 12.6% of managers and 4.5% of employees are undecided, 9% of employees and 4.5% of managers partially disagree, and 3.6% of employees in organizations do not agree at all.

Table 1.Difference between managers' and employees' attitudes regarding leadership style and positive impact on employee performance

				I don't agree at all	Partly disagree	Uncertain/ don't know	Partly agreed	Totally agree	Total
position		Count	1	0	0	0	0	0	1
		% within **position**	100,00%	0,00%	0,00%	0,00%	0,00%	0,00%	100,00%
		% of Total	0,70%	0,00%	0,00%	0,00%	0,00%	0,00%	0,70%
	employees	Count	0	4	10	14	27	56	111
		% within **position**	0,00%	3,60%	9,00%	12,60%	24,30%	50,50%	100,00%
		% of Total	0,00%	3,00%	7,50%	10,40%	20,10%	41,80%	82,80%
	managers	Count	0	0	1	1	11	9	22
		% within **position**	0,00%	0,00%	4,50%	4,50%	50,00%	40,90%	100,00%
		% of Total	0,00%	0,00%	0,70%	0,70%	8,20%	6,70%	16,40%
Total		Count	1	4	11	15	38	65	134
		% within **position**	0,70%	3,00%	8,20%	11,20%	28,40%	48,50%	100,00%
		% of Total	0,70%	3,00%	8,20%	11,20%	28,40%	48,50%	100,00%

In order to determine if there is a difference between the attitudes of managers and employees regarding leadership style and the positive impact on employee performance, we performed statistical processing of the obtained data with a chi square test. The value of Asymp. The Pearson Chi-Square Sig is .000 and

we accept that there is a statistically significant difference between the attitudes of managers and employees.

Table 2. Chi-Square Tests - Determining a statistically significant difference between the attitudes of managers and employees

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	140,925[a]	10	0
Likelihood Ratio	19,041	10	0,04
N of Valid Cases	134		

Regarding the impact of executive coaching and proactive influence among employees from it, we obtained the following results:

Table 3. The influence of executive coaching and proactive influence among employees

				I don't agree at all	Partly agree	Uncertain/ don't know	Partly agree	Totally agree	Total
position		Count	1	0	0	0	0	0	1
		% within **position**	100,00%	0,00%	0,00%	0,00%	0,00%	0,00%	100,00%
		% of Total	0,70%	0,00%	0,00%	0,00%	0,00%	0,00%	0,70%
	employees	Count	0	3	11	22	31	44	111
		% within **position**	0,00%	2,70%	9,90%	19,80%	27,90%	39,60%	100,00%
		% of Total	0,00%	2,20%	8,20%	16,40%	23,10%	32,80%	82,80%
	managers	Count	0	0	1	4	8	9	22
		% within **position**	0,00%	0,00%	4,50%	18,20%	36,40%	40,90%	100,00%
		% of Total	0,00%	0,00%	0,70%	3,00%	6,00%	6,70%	16,40%
Total		Count	1	3	12	26	39	53	134
		% within **position**	0,70%	2,20%	9,00%	19,40%	29,10%	39,60%	100,00%
		% of Total	0,70%	2,20%	9,00%	19,40%	29,10%	39,60%	100,00%

In order to determine whether there is a difference between the attitudes of managers and employees regarding the impact of executive coaching and the impact on proactive influence among employees of the same value of Asymp. The Pearson Chi-Square Sig is .000 and we accept that there is a statistically significant difference between the attitudes of managers and employees.

Table 4. Chi-Square Tests - statistically significant difference between the attitudes of managers and employees

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	135,671a	10	0
Likelihood Ratio	14,019	10	0,172
N of Valid Cases	134		

Regarding the impact of executive coaching and the impact on new proposals and generating ideas among employees, we obtained the following results:

Table 5. Executive coaching and influencing new proposals and generating ideas among employees

				I don't agree at all	Partly disagree	Uncertain/ don't know	Partly agree	Totally agree	Total
position		Count	1	0	0	0	0	0	1
		% within **position**	100,00%	0,00%	0,00%	0,00%	0,00%	0,00%	100,00%
		% of Total	0,70%	0,00%	0,00%	0,00%	0,00%	0,00%	0,70%
	employees	Count	0	3	11	22	31	44	111
		% within **position**	0,00%	2,70%	9,90%	19,80%	27,90%	39,60%	100,00%
		% of Total	0,00%	2,20%	8,20%	16,40%	23,10%	32,80%	82,80%
	managers	Count	0	0	1	4	8	9	22
		% within **position**	0,00%	0,00%	4,50%	18,20%	36,40%	40,90%	100,00%
		% of Total	0,00%	0,00%	0,70%	3,00%	6,00%	6,70%	16,40%
Total		Count	1	3	12	26	39	53	134
		% within **position**	0,70%	2,20%	9,00%	19,40%	29,10%	39,60%	100,00%
		% of Total	0,70%	2,20%	9,00%	19,40%	29,10%	39,60%	100,00%

The value of Asymp. The Pearson Chi-Square Sig is .000 and we accept that there is a statistically significant difference between the attitudes of managers and employees regarding executive coaching and the impact on new proposals and idea generation among employees in enterprises.

Table 6. Chi-Square Tests statistically significant difference between the attitudes of the impact on new proposals and idea generation among employees

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	137,872[a]	10	0
Likelihood Ratio	16,194	10	0,094
N of Valid Cases	134		

In terms of the impact of executive coaching on the comfort of interpersonal communication, in terms of the impact of executive coaching on freedom of expression of employees, in terms of innovation, then the impact of executive coaching on freedom of expression of employees, inspiration for courageous activity among employees initiated by leaders, the relationship of executive coaching on self-initiative and the generation of ideas for innovative performance among employees as well as the creation of new methods for achieving results, then how the leader influences employees to be responsible for achieving results, the opinions of managers and employees, as well as how much coaching maximizes the creative potential of the leader, and the leader encourages the creative potential of the employees, and lastly, how much the managers and employees are inspired to contribute new services, products and processes to the organization were the rest of the questions that were addressed at the same way and in the tables for skeoia of them it is valid that the value of Asymp. Pearson's Chi-Square Sig is .000 which accepts that there is a statistically significant difference between the attitudes of managers and employees regarding the highlighted statements on a Likert scale.

4. CONCLUDING OBSERVATIONS

In this paper we examined the views of leaders who have gone through executive coaching and employees working in the same organizations. Our goal was to perceive some influence between the behavior of the leader towards the employees in terms of improving the innovation performance of the employees, and also to perceive the attitudes of the leaders regarding the experience of executive coaching and the performance. The analysis of the results showed that regarding most issues there is a significant difference in attitudes between leaders and employees in the organization. Regarding the leadership style and how it affects the performance of the employees, we obtained the following results: most of the employees declared themselves as fully agreeing (50.5%) and 40.9% of the managers declared themselves as fully agreeing. 24.3% of employees and 50% of managers partially agree. 12.6% of managers and 4.5% of employees are undecided, 9% of employees and 4.5% of managers partially disagree, and 3.6% of company employees do not agree at all. It means that executive coaching worked to change the leadership style but did not make complete transformations. This, in turn, encourages some of the employees towards better innovation performances. Executive coaching in approximately 70% influenced opening to new ideas, but also such an approach was felt by more than 50% of employees who generated and opened to share new ideas. The freedom in expressing the views of the employees in relation to innovations is at a satisfactory level of approximately 60%, while managers (58.6 %) also opened up to hearing the opinions of employees in relation to innovations after the coaching process. The leader greatly encourages creative thinking and energy, and the awakening of creative potentials, and the fact that employees and managers are equally inspired and contribute to new services, products or processes in the organization is pleasing. The field of coaching processes and their practical application are insufficiently researched and they should lead us to opening new practices for personal development in the context of organizational progress and innovative performance.

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Original research

CROSS FUNCTIONAL TEAMS: A KEY FOR IMPROVING SYSTEMS THINKING IN AN ORGANIZATION

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Abstract: To improve systems thinking in micro, small and medium-sized organizations, the main efforts should be aimed towards enhancing the capacity and competence for analyzing, understanding and optimization of established systems in an organization. As Katzenbach and Smith elaborated expertly in 1993, a cross functional team represents a composition of multiple people with various organizational functions regardless of hierarchy, but tactically chosen for their complementary skills and committed to a common organizational vision and goal (Katzenbach & Smith, 1993). This paper explores the thesis that cross-functional teams are a key pillar in the development of the systems thinking capacity of any small to medium organization. The author will review the relevant and available literature defining teams, cross functional teams, will provide an insight into the works of various contemporary authors in systems thinking thus providing a descriptive analysis on the thesis.

Keywords: DSRP, cross-functional, team, VUCA

1. INTRODUCTION TO SYSTEMS THINKING: THE FIELD WITHOUT AN EXACT DEFINITION.

Systems thinking, as a field so expertly detailed in the seminal work of Peter Senge, is one of the five fundamental capacities a company needs to obtain or nurture to remain competitive, flexible, and future proof (Senge, 1990). A lot of papers are published on the topic, and even though as a phenomenon it exists even in the earliest societies, it hasn't been clearly defined yet. Authors like Krystina Stave and Megan Hopper have determined that system thinking exists beyond the social sciences while examining the works from various disciplines. What they've concluded is that although different fields approached defining systems thinking in different ways, most of them carry common characteristics. Stave and Hoper ever so expertly created an overview of the characteristics on the different approaches:

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Table 1. Mutual characteristics between various definitions of systems thinking (Stave & Hopper, 2007)

Characteristic	**Description**	**Level**
Recognizing interconnectedness	Holistic approach towards systems, understanding on how different parts are connected to form a whole	Basic
Identifying feedback	Recognizing and differentiating the interconnectedness and feedback loops	Basic
Understanding dynamic behavior	Understanding the relationship between feedback and behavior	Basic
Understanding flows and variables	Understanding the various variables and their influence overflows	Middle
Using conceptual models	Using general system principles to define, explain or elaborate and idea or a process	Middle
Creating simulation models	Describing relationships through statistical and mathematical values, using qualitative and quantitative variables	Advanced
Creating and testing policies	Using simulations to establish and test policies	Advanced

This table represents the most used characteristics between the various efforts to define the field of systems thinking (Stave & Hopper, 2007). There is a significant discourse between the understanding of the systems thinking and its application within the modern organizations (Cabrera, 2006). As identified in the authors` previous research, systems thinking as a metacognitive organizational competence is seriously underdeveloped in the region of south-east Europe, therefore necessitating the need for the development of a practical model for improvement.

Inspired by Arie de Geus, and Peter Senge with his seminal work "The Fifth Discipline", and heavily influenced by the contemporary researcher Derek Cabrera, PhD, the author of this paper will try to illustrate few key policies and models for improvement of the systems thinking within the modern organization. Moreover, the paper will focus on previous research illustrating various (and immediate) effects of the system's thinking when put into practice through utilizing cross functional teams.

2. DEFINING CROSS-FUNCTIONAL TEAMS

A cross-functional team is any group of people with different functional expertise working together for a common goal (Santa et al., 2010), in other words it is the cooperation or collaboration of individuals drawn from separate functional areas (Pinto et al., 1993). Contemporary organization, as researched from the year 2000 till now, suggests that the use of cross-functional teams is closely associated with performance, especially in terms of project performance (Santa et al., 2010). The research on cross-functional teams starts even earlier, where a study done by Henke et al, truly encapsulates the use and value of teams. They suggest that the four primary benefits of utilizing cross-functional teams are:

1. The shortcomings of the organization's hierarchy are overcome by the team's ability to cut across traditional vertical lines of authority.
2. Decentralized decision making
3. Hierarchical information is reduced.
4. Significantly greater chance of higher quality decisions in teams rather than individuals (Henke et al., 1993).

In opposition to the definition, the use or the value of teams is the existence of vertical hierarchy as a concept. For over two millennia, society has had countless evidence of different hierarchical systems being utilized and developed, de facto establishing the hierarchy as a dominant organizational system for sustainability and/or longevity. Teams on the other hand

have just appeared, and in comparison, teams are in their infancy stages. Even though teams are now in their infancy stages, Henke et al, note that there is already a symptom which they promptly name "Team Overuse". They regard that team as a phenomenon is not the one-size-fits-all issues and jobs within a company, and sometimes, especially in crisis mode, a hierarchy system, or a centralized system of decision making makes more sense (Henke et al., 1993).

3. SYSTEMS THINKING AND CROSS-FUNCTIONAL TEAMS - ANSWER FOR THE VUCA WORLD.

When we look at organizations that have stood the test of time, we often gain insight that some of the factors included the ability to be agile and adaptable. Due to market ever-changing trends or resource scarcity, an organization should be able to be flexible to overcome most of the obstacles and carry on their value production (Nafei, 2016). As noted in the paper from Ariffin and Purwanti, recent research shows that there is a distinct urgency for companies to bring various levels of flexibility to their projects, processes and even leadership in order to be able to thrive in the new era which is stated to be changing volatilely, uncertainly, complex and with a lot of ambiguity (Ariffin & Purwanti, 2023). Plenty of researchers and company leaders refer to the future as: VUCA which stands for Volatile, Uncertain, Complex and Ambiguous (Lawrence, 2013). As explored in the work of Paul Kinsinger and Karen Walch, both Ph.D.'s in Thunderbird University, they noted that plenty of USA companies borrowed this term from the U.S. military and really leaned into it in at the financial troubles of the US market between the years 2008-2009 (Kingsinger & Walch, 2012). Although the term was established in the 90es to explain the new global battlefield, it seems to have really fit the modern business environment, with many micro, small or even major elements appearing and as Thomas Friedman says, 'flatten the world' (Friedman, 2005).

By utilizing cross-functional teams, an organization will inadvertently achieve higher productivity, increased critical thinking and problem-solving capabilities thus fostering system thinking capacity (Pinto et al., 1993). To explore the connection, this paper offers several key areas of improvement which relate directly to system thinking competences. These areas include an overview of the cross functional team competences aligned to the DSRP model developed by the Cabrera Lab, and its creator, professor Derek Cabrera PhD (Cabrera et al., 2022).

3.1. Diverse perspectives, holistic approach, and improved decision-making by strengthening distinction

Cross-functional teams bring together individuals from different departments, hierarchical levels, functions, or disciplines within the organization. Each member brings their unique perspective and expertise to the table, enabling a more comprehensive understanding of the system (Mirghani et al., 2004). What this entails is a unique team competence to offer multiple perspectives on an issue, product, problem or even on the higher echelons of decision making. It is upon the management to ask the team to establish good collaboration principles to overcome the pitfalls of having lots of diverse and oftentimes contradictory perspectives on issues. In other words, management has the obligation to encourage healthy dialogue, to enable the team to transcend their inherent differences instead of traversing them. It is crucial in team cohesion to establish principles to avoid interpersonal conflicts, to foster creative scaffolding of problem solving and encourage continued creation and mindset flexibility in the team members (Majchrza et al., 2011).

By considering various perspectives, cross-functional teams are better equipped to analyze complex problems from multiple angles. This holistic approach to problem-solving encourages members to think beyond their individual roles and consider the broader implications of their decisions on the entire system, thus reducing the risk of making an error in judgement (Santa et al., 2022). In turn, this lowering of risk enables teams to be open to new challenges or possibilities instead of dealing with consequences.

While exploring the perspectives angle (P) as a key component of systems thinking in Macedonian organizations in a separately conducted research (October - December 2023, n=169), almost sixty percent of the participants have said that it is extremely easy for them to see things/jobs/objects/ideas from multiple perspectives (Scenario 1.2: 59.2% n=169). However, when asked about changing their decisions or plans regarding utilizing multiple perspectives (Scenario 1.4), only 23.1% of respondents find it extremely easy to do so. What is even more symptomatic is that even less respondents find it easy to switch their views, plans, or decisions when others present them with different perspectives (Scenario 1.5: 16.1%). This indicates that there is a slight discourse between the belief and easiness of looking at things from multiple perspectives and willingness to let those perspectives influence decisions and stances. What is interesting to note is that Macedonian managers and employees of micro and small companies self-reflect on Perspectives and Distinction capacities as quite competent, where in almost all the scenarios offered, they noted extreme easiness at the task at hand (2.1-2.6 average above 60% n=169)

Table 2. Findings of section: Perspectives in reality / P Scenarios

1. Perspectives in reality / P scenarios	**Extremely difficult (1)**	**(2)**	**(3)**	**(4)**	**Extremely easy (5)**	**Distribution**
1.1. I can see the system where I work from multiple perspectives to better understand it	1.8%	7.1%	16.6%	36.7%	37.9%	
1.2. I believe that any job/object/idea can be seen from multiple perspectives	1.8%	1.8%	17.8%	19.5%	59.2%	
1.3. I understand how my work, or my work outputs can be seen from different stakeholders.	3.6%	5.3%	16.0%	33.1%	42.0%	
1.4. I change the decision or a plan after I look at things from multiple perspectives	4.7%	8.9%	27.8%	35.5%	23.1%	
1.5. I change the decision or plan after others present me with different perspective	5.9%	14.2%	30.8%	32.5%	16.6%	
1.6. While utilizing one or little perspectives, the margin for error grows	9.5%	14.8%	26.0%	26.6%	23.2%	
AVERAGES	**4.6%**	**8.7%**	**22.5%**	**30.7%**	**33.7%**	

Distinction as a competence, observed in the findings is on a much higher scale of development. As noted, above 60% of the answers are in the fifth column, where the participants have said that they find it extremely easy to distinguish things in the various scenarios offered. One scenario to further analyze is the 2.4 where the answers are in comparison, a bit more flattened, which may suggest that people in organizations may not find

it so easy to use specific details when explaining ideas or things to others (scenario D 2.4 = 23,1(3)<->45,6%(5))

Table 3. Findings of section: Distinction in reality / D Scenarios

Distinction in reality / D Scenarios	Extremely difficult (1)	(2)	(3)	(4)	Extremely easy (5)	Distribution
2.1. When I receive a job or a task, I can distinguish between what is the task and what it is not	0,6%	3,0%	16,6%	18,3%	61,5%	
2.2. I distinguish who is my superior/manager and who is not in the organization where I work	1,2%	2,4%	14,2%	11,2%	71,0%	
2.3. I can describe my job or my job products in details and clearly	1,2%	3,0%	13,6%	16,6%	65,7%	
2.4. I use specific details when describing an idea or a thing	1,2%	4,7%	23,1%	25,4%	45,6%	
2.5. I can conclude when the job is fully done	0,6%	1,2%	14,2%	16,6%	67,5%	
2.6. I can clearly distinguish when I am collegial and when I am not.	1,8%	2,4%	16,6%	24,3%	55,0%	
AVERAGES	**1,1%**	**2,8%**	**16,4%**	**18,7%**	**61,1%**	

3.2. Understanding relationships, systems, and their importance in a VUCA environment

This VUCA paradigm of modern society, really puts into perspective the need for a team that has a highly developed competency for system thinking – especially the competency to understand systemic relations, relationships, and whichever influences there might result of those relationships (Cabrera & Cabrera, 2018).

Systems thinking as a team competency, begins through developing understanding of systems primarily. What this entails is developing understanding of all the meta-connections, relationships, and their mutual influences within a system (Cabrera et al., 2022). Although this is key evidence for establishing cross-functional teams, this competency, however, needs close and targeted nurturing by the leadership as noted by the authors research (October - December 2023, n=169).

In his work, Dr. Derek Cabrera notes that the problems companies are facing nowadays are quite often wicked, meaning the modern problems usually do not have simple solutions. Even so, he urges companies to consider organizational learning as a key part to developing organizational immunity and agility, especially systems thinking (Cabrera & Cabrera, 2018). As the findings show, Macedonian small and micro companies do have the potential for systems thinking, especially shown in the systems understanding scenarios (3.1 – 3.6 n=169).

One of the key observations within these findings is the 3.3 scenario, where the answers are mainly distributed from the median to the right ((3) - extremely easy (5)), suggesting that more formal transparency might exist between the hierarchy levels. The findings suggest that employees, within their work environment, feel competent and can explain, describe, or see the systems which they are part of, easy or extremely easy.

Table 4. Findings of section: Systems in reality / S Scenarios

Systems in reality / S Scenarios	Extremely difficult (1)	(2)	(3)	(4)	Extremely easy (5)	Distribution
3.1. I can describe how the effects from my job influence the organizational vision or mission	0,6%	3,6%	19,5%	29,6%	46,7%	
3.2. I understand how my job/job products influence my team or sector colleagues	1,8%	1,8%	19,5%	22,5%	54,4%	
3.3. I can explain the way of decision making and planning in my organization	5,3%	7,7%	26,6%	24,9%	35,5%	
3.4. I can explain how different parts/sectors/divisions cooperate within my organization	3,0%	9,5%	18,9%	24,9%	43,8%	
3.5. I can look at my organization from afar (as a whole) and to see the separate parts	3,6%	7,7%	16,6%	26,6%	45,6%	
3.6. I understand and can describe the system of processes, resources, and information in which I work	1,2%	5,9%	17,2%	24,9%	50,9%	
AVERAGES	**2,6%**	**6,0%**	**19,7%**	**25,6%**	**46,2%**	

Table 5. Findings of section: Relations in reality / R Scenarios

4. Relations in reality / R scenarios	Extremely difficult (1)	(2)	(3)	(4)	Extremely easy (5)	Distribution
4.1. The Relations I have established at a professional level within the scope of my job are clear to me."	0,6%	3,6%	14,2%	25,4%	56,2%	
4.2. I can observe or describe all the relationships that exist within my organization.	1,8%	8,3%	22,5%	26,6%	40,8%	
4.3. I can recognize the connection between my work and the company's vision.	4,1%	7,1%	12,4%	33,7%	42,6%	
4.4. I can relate the compensation/salary/fee I receive to my work tasks.	6,5%	8,9%	24,3%	25,4%	34,9%	
4.5. Within the organizational hierarchy, I recognize the informal relationships that exist and how they affect organizational decisions.	1,8%	4,7%	20,1%	37,9%	35,5%	
4.6. I can explain the reaction or effect of my actions or products.	1,8%	2,4%	17,2%	31,4%	47,3%	
AVERAGES	**2,8%**	**5,8%**	**18,5%**	**30,1%**	**42,9%**	

Looking holistically at the findings for the R scenarios, in comparison to the other three segments of the DSRP Model, it is observed a more evenly distributed answers, although still with a distinguished right (extremely easy) bias. However, further research into the scenarios

such as 4.4 and 4.5 should offer more insight into how to develop the Relations competency for system thinking in an organization. On the other hand, such disadvantages are easily overcome by utilizing cross-functional teams.

4. CONCLUSION

What recent research into organizational agility offers is an insight into the VUCA environment of today's business world. The research further expands this by a comparison of the mental models utilized within the organization's managerial capacities. Such observation is made in the works of Dr. Cabrera, where he compares the different complexities of the VUCA and the methods how we address those complexities – the LAMO thinking model (Linear Anthropocentric Mechanistic Ordered). Cabrera refers to the fact that the real world is non-linear and is a huge interconnection of cause-effect webs – where our thinking is most often linear and only considers the causal ways (Cabrera & Cabrera, 2018). The world itself is adaptive, organic and ever-evolving – however our understanding of the world is often done through mechanistic metaphors (universe works like a clockwork, the brain operates the same as a computer etc.). Furthermore, Cabrera explains that the world is multivalent by design (and-both can be true at the same time) but in comparison, the LAMO thinking entails bivalency: Either-Or thinking. Lastly, humankind often thinks from a human-centered perspective, whereas the world is quite human agnostic (as recently proven by the Covid-19 pandemic) (Cabrera, 2020).

Cross-functional composition of teams should enable companies **to breakdown the traditional siloed departments** that focus almost exclusively on their specific functions. By promotion of collaboration and meta-communication between the various parts of the organizations, a synergistic and more interconnected work environment is fostered. This is one of the key conditions for the development of systems thinking competency. Additionally, by such cross-functional collaboration, innovation and creativity is fueled and emboldened. Cross functional teams solve not only their departments' problems, but by collaborating they succeed in solving more of the web of problems that are inherently interconnected. Even more so, team members often note an increase in their competency to come up with novel ideas, perspectives or even solutions based on the collective knowledge, skills, and experience of the team members. Going even further, cross-functional teams are one of the answers of the VUCA world, and that is simply because one of the key characteristics of such teams is agility and adaptability. By being equipped with various skills, backgrounds and experiences, the teams can quickly and with less effort answer changes and disruptions because they can quickly utilize resources from various parts of the organizations and adjust to the volatile playing fields accordingly.

Overall, cross-functional teams play a vital role in promoting systems thinking within an organization by fostering collaboration, innovation, and holistic problem-solving across different functional areas.

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Original research

THE DEVELOPMENT OF E-CRIMES IN THE DIGITAL ECONOMY: CAUSES AND CONSEQUENCES

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Abstract: As technology continues to improve, e-crime poses a huge threat to the global economy. According to the World Cyber Security Report (2023), vulnerabilities in the digital world are growing along with technological innovation, which is driving e-crime (World Economic Forum, 2023). This research shows that more and more organizations and countries are facing cyber challenges, making it necessary to strengthen global cyber resilience. In addition, the report indicates that economic losses due to cyber-attacks could reach up to US$ 23.84 trillion worldwide by 2027, almost tripling the growth compared to 2022 (World Economic Forum, 2023). These data confirm that e-crimes pose more and more difficulties for the stability of the international economy. According to the research by PricewaterhouseCoopers in 2022, e-crime is the main cause of external fraud in organizations, so it is important to understand the impact of these crimes and find ways to control them (PwC, 2022). The growing prevalence of cybercrime poses significant challenges to the digital economy, affecting both individuals and organizations. This article examines the theoretical aspects of the cybercrime concept. The conclusions are based on a combination of theoretical analysis and empirical research conducted in Lithuania. By understanding the underlying factors and the extent of their impact, the aim is to offer actionable recommendations to increase digital resilience to e-crime threats.

Keywords: E-crimes, digital economy, cyber security, preventive measures, digital resilience.

1. INTRODUCTION

*Relevance of the topic***.** Although the topic of e-crimes is widely researched worldwide, there is a lack of specific research dedicated to the demographics of Lithuania and how counter-strategies and actions are formed in the country and the region in response to digital threats. According to the OECD (2020 report), Lithuania, like many other countries, faces increasing threats of e-crimes, which affect economic stability and security. The report emphasizes that

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the country's economy must be ready to counter not only current but also future cyber attacks, which may arise due to current geopolitical tensions and technological changes (OECD, 2022). In addition, the CISCO report emphasizes that global e-crimes cause huge economic damages every year, and this trend is also noticeable in Lithuania. The report identifies the economic toll of cyberattacks, emphasizing that addressing these challenges requires international cooperation and innovation in security technologies (CISCO, 2020). The novelty of this study is the detailed analysis of Lithuania's demographics, which allows a more detailed understanding of how these threats specifically affect the local economy and what specific decisions need to be taken to ensure a more effective response to cyber challenges.

Scientific problem - what factors determine the development of e-crimes in the digital economy in Lithuania, and what are the consequences of these crimes for the country's economy and society?

The purpose of the study is to assess the impact of the development of e-crimes on the digital economy of Lithuania and identify the main causes of these crimes based on the literature and after examining the users' attitude.

Research methods: analysis of scientific literature, survey.

2. THEORETICAL ASPECTS OF THE CONCEPT OF E-CRIMES

2.1. Concept and types of e-crimes

E-crime in the digital age is driven by a variety of factors that exploit the opportunities and vulnerabilities created by widespread digital technologies. One of the main reasons is the anonymity and global reach provided by the Internet, which allows criminals to conduct illegal activities beyond traditional geographic boundaries (Chudasama & Deora, 2021). The interconnectedness of digital systems and the sheer volume of data exchanged create lucrative targets for cybercriminals seeking financial gain or disruption.

The increasing digitization of financial transactions and sensitive information opens new opportunities for exploitation, making e-crime an attractive option for individuals and organized crime groups. The potential for profit, coupled with the inherent difficulty in identifying and prosecuting cybercriminals, continues to encourage this activity (Chudasama & Deora, 2021). Thus, the rapid development of technology, while beneficial in many respects, also provides new attack opportunities and vulnerabilities that can be exploited by malicious actors. As advances in artificial intelligence, the Internet and cloud computing continue to redefine the digital landscape, cybercriminals are adapting their tactics to take advantage of new technologies.

E-crime covers a wide range of illegal activities that directly affect the digital economy. The following types of e-crimes are (see Table 1).

In summary, e-crimes is a term used to describe criminal activities where computers or computer networks are used as a tool to carry out criminal activities (Chudasama & Deora 2021). These activities include data and identity theft, online fraud and theft, malware, hacking and other cyber-attacks.

Table 1. Types of e-crimes

Author	E-crime	Description
Brush & Cobb, 2021	*Identity theft*	Identity theft involves the unauthorized acquisition and fraudulent use of a person's personal information, such as social security numbers, credit card information, or other identifying information. This type of e-crime can result in financial and reputational losses for individuals and legal and compliance consequences for businesses.
Varghese, 2016	Hacking	Hacking is the unauthorized access to computer systems, networks, or devices to compromise security, steal information, or disrupt operations. It is a widespread e-crime that poses a significant risk to the confidentiality, integrity and availability of digital assets
Al – Khater et al., 2020	Phishing	Data theft is a form of e-crime that involves fraudulent attempts to obtain sensitive information such as usernames, passwords and financial information by masquerading as a trusted electronic entity. Phishing attacks can lead to unauthorized access to personal and financial accounts, as well as damage the reputation of targeted organizations.
Varghese, 2016	Online fraud	Internet fraud includes a variety of fraudulent schemes conducted online, including but not limited to investment fraud, auction fraud, and credit card fraud. These fraudulent activities can have far-reaching financial consequences for individuals, businesses and financial institutions and undermine confidence in digital transactions.
Neufeld, 2010	Cyber extortion	Cyber extortion involves the use of threats or coercion to demand payment or other benefits in exchange for or non-disclosure of sensitive confidential data, disruption of systems or the commission of further e-crimes. It is a crime of increasing concern that can cause significant financial and reputational damage to victims.
The National Fraud Center, Inc., 2000	Ransomware	Malware is a type of equipment that encrypts or locks a victim's files from a computer, demanding a ransom payment in exchange for regaining access. This is a particularly insidious form of e-crime that has become more and more common in recent years. It is often spread through phishing emails. emails or by exploiting a software vulnerability, and once the system is "infected", the victim is effectively held hostage until the ransom is paid.
Brush & Cobb, 2021	Cryptojacking	E-crime uses scripts to secretly mine cryptocurrencies directly from web browsers without explicit user consent. These insidious attacks often involve installing cryptocurrency mining software on the victim's system. Many cryptocurrency exploits use JavaScript code to perform mining operations in the browser when users accidentally access malicious websites or have tabs or windows open on such websites. Notably, there is no need to install traditional malware, as simply visiting the compromised web page launches the mining code in the browser.
Tolosana, et al., 2020	Deepfakes	Deep video spoofing is the use of artificial intelligence and machine learning to create highly realistic videos, audios, or images that depict individuals speaking or doing things that were not actually there. These manipulated media can be used to deceive and manipulate viewers, often with malicious intent. The creation and distribution of counterfeits is a major threat in various fields, including politics, business, and can lead to significant financial losses, damage to sensitive information, or damage to reputation.
Tolosana, et al., 2020	Manipulation of biometric authentication	Cybercriminals use sophisticated techniques to bypass biometric security measures. For example, fake fingerprints or facial images created using AI algorithms can be used to trick biometric recognition systems to gain unauthorized access to devices, applications or protected locations.
Earhart, 2023	Cyberbullying	It is the use of electronic communications to bully, harass or intimidate individuals. This can take many forms, such as spreading rumours, threats or derogatory comments on social media, instant messages or other online platforms. An example of cyberbullying is the targeted harassment of a student through anonymous messages on a school's social media page, causing emotional distress and affecting the victim's well-being and academic performance.

2.2. Causes of E-Crimes

The causes of e-crime are diverse and multifaceted, as e-crime can be attributed to a combination of social, economic, political, technological and cyber security factors. These

factors interact and influence each other, creating a complex environment that encourages the emergence and spread of e-crime. Chen et al. (2023), in a study on the global geography of e-crime and its drivers, reviewed the existing empirical literature and integrated various criminological theories and proposed a conceptual framework for examining the drivers of e-crime. The system consists of five interrelated components: social, economic, political, technological and cyber security factors. The possible trajectories through which each component can directly or indirectly affect e-crimes are illustrated (see Figure 1). The author shows the positive and negative effects on e-crimes with "+" and "-" signs.

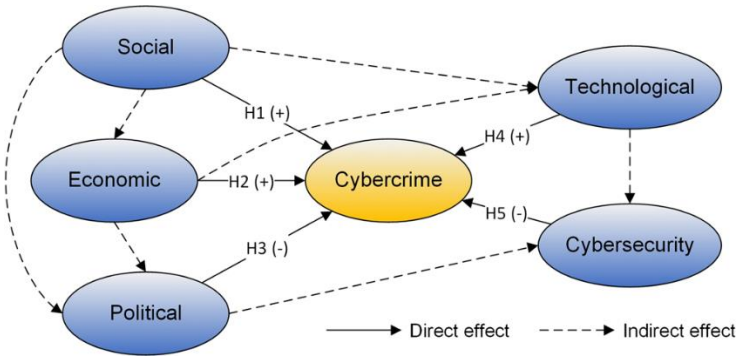

Figure 1. A conceptual framework for analyzing the driving forces of e-crime (Chen et al., 2023)

Social Factors: Changes in society and widespread dependence on technology have created new opportunities and motivations for individuals to engage in e-crime. Widespread Internet connectivity and dependence on digital platforms create an enabling environment for e-criminal activities, including fraud, identity theft, and cyberbullying. The anonymity and global reach of the Internet has helped cybercriminals exploit and victimize vulnerable individuals (Clough, 2012). This highlights the role of societal change in creating opportunities for e-criminal activity.

Psychological factors such as thrill- and adrenaline-seeking behavior, the desire for power and control, and the need for recognition can also lead individuals to engage in e-crime. Some individuals may be motivated by the challenge of circumventing security measures or the satisfaction of outwitting authorities. The anonymity afforded by the Internet allows such psychological satisfaction to be experienced, encouraging individuals to engage in illegal activities that they would not consider doing in an off-line environment.

In the context of business and organizations, corporate culture and norms also influence the likelihood of e-crime. Pressure to meet financial targets, lack of supervision and a culture that prioritizes results over ethical behavior can lead employees to engage in activities such as embezzlement and data theft (Chen et al., 2023). Poorly managed organizational structures and inadequate internal controls can also create an opportunity for e-crime to occur in the corporate environment. Inside threats, such as disgruntled employees, negligent individuals, or individuals coerced by external actors, can use their access and privileges to commit e-crimes such as data breaches, intellectual property theft, or sabotage. This highlights the importance of robust access controls, employee training and continuous monitoring to prevent and detect e-crime originating from within an organization.

Economic Factors: Economic difference, poverty and unemployment can also encourage individuals to commit e-crimes. The allure of financial rewards combined with financial pressure and lack of legitimate employment opportunities encourage individuals to engage in

various forms of e-crime such as online fraud, fraud schemes and financial e-crime (Riaz & Riaz, 2015). The study highlights the link between economic factors and e-crime, highlighting the need for socio-economic interventions to address the root causes of cybercriminal behaviour.

Political factors: Political and geopolitical conflicts and tensions can lead to cyber-attacks and e-crimes as a form of espionage, sabotage or disruption (Chen et al., 2023). State-sponsored e-crime, industrial espionage, and politically motivated cyber-hacking are examples of how political dynamics can drive malicious activity in the digital realm. Reports from global cybersecurity firms such as McAfee and Symantec document the involvement of nation-state actors in cyberespionage and the use of sophisticated e-crime techniques to achieve political goals. One of the main reasons individuals and organizations engage in e-crime for political purposes is the potential to cause damage, disrupt operations, and compromise the integrity of systems and data for political gain. State-sponsored e-crimes aimed at espionage, sabotage or disruption are often driven by political tensions, competition and strategic interests. Political actors may engage in cybercrime activities by attempting to gather intelligence, manipulate information, or undermine adversary operations for geopolitical advantage.

Technological and Cybersecurity Factors: Rapid advances in technology, particularly in areas such as artificial intelligence, cryptocurrency and the Internet of Things (IoT), have created new opportunities for cybercriminals to exploit vulnerabilities and conduct sophisticated e-crime operations (Buck, 2017). The Accenture report of 2021 identifies the convergence of new technologies as a driving force behind the evolution of e-crime and highlights the need for robust cyber security measures to mitigate the associated risks. In addition, the report discusses the growing threat of ransomware attacks, supply chain vulnerabilities, and the use of cloud services.

The global nature of digital communication and the borderless nature of the Internet create opportunities for e-crime to transcend geographic boundaries. Cybercriminals can launch attacks from remote locations, hide their identities using anonymizing technologies, and take advantage of differences in international regulations and law enforcement capabilities. The interconnectedness of the digital world amplifies the challenges of investigating and prosecuting individuals for e-crimes, leaving criminals with no fear of punishment (Grimes, 2014).

The links of digital systems and the widespread sharing and storage of data create lucrative targets for cybercriminals seeking financial gain or intent to cause disruption. The increasing digitization of financial transactions and sensitive information provides new opportunities for exploitation, making e-crime an attractive opportunity for individuals and organized crime groups. The potential for large financial gains and the challenges of identifying e-criminals further drive e-crimes. Weaknesses in cyber security practices, inadequate protection of sensitive data, unpatched software and failure to implement effective security measures and lack of awareness of cyber threats create opportunities for cyber criminals to exploit vulnerabilities and commit e-crimes (Riaz & Riaz, 2015). Although as technology expands in all everyday areas, so does the perception of threats, but statistics still show increasing numbers of e-crime (Brici et al., 2022).

In summary, the causes of e-crime are diverse and interrelated, involving social, economic, political, technological and cyber security aspects. In order to effectively combat digital threats and protect individuals and organizations from the harmful effects of e-criminal activities, it is necessary to consider these key factors and implement comprehensive e-crime prevention strategies.

3. DATA AND METHODOLOGY

3.1. The survey sample

A carefully selected sample that is representative of the study population is essential to ensure accurate data analysis and interpretation. In order to reflect the attitude of Lithuanian residents who have access to the Internet to e-crimes, the survey was intended for this audience. In 2023, in Lithuania, the level of internet usage reached 88.9%, which is about 2.43 million of internet users.

After receiving 413 survey responses using the Cochran formula (see formula 1), the estimated error (precision) is approximately 0.0301, or 3.01%. this means that with a 95% confidence level it can be expected that the actual share of the Internet user population in Lithuania will be within 3.01 percentage points of the results of the survey.

$$n_0 = \frac{Z^2 \times p \times (1-p)}{e^2} \quad (1)$$

where

n_0 – sample size,

Z – value (e.g., 1.96 at 95% confidence level),

p is the estimated proportion of the population that has the trait of interest (if unknown, 0.5 is used because it gives the largest sample size),

e is the desired level of precision (margin of error, e.g. 0.05, i.e. 5 percent).

3.2 User survey method

For a study aimed at analyzing the development of e-crimes in the digital economy, the quantitative survey method chosen is appropriate, as it allows objective assessment and calculation of data collected from a wide range of respondents. A quantitative survey is valued for its ability to apply statistical analysis, which provides a scientific basis for testing hypotheses and formulating conclusions. This method is widely used in social science research, especially research related to cyber security, because it allows for the efficient identification and analysis of behavioral patterns and attitudes related to cyber security threats. According to Almansoori et al. (2023), the quantitative survey method allows obtaining significant and objective data on trends in cyber-behaviour. Also, it is argued that statistical analysis allows to identify relationships between different variables and to assess the extent of impact, which is important for the formulation of preventive strategies and policy measures aimed at reducing e-crimes in the digital economy.

The quantitative survey provides an opportunity to clearly understand how different demographic and professional aspects affect respondents' attitudes towards cyber challenges and their solutions.

The study, using a quantitative method, was carried out in 2024 from April 19 to May 6, using the online survey platform Google Forms, which ensured fast and efficient data collection and anonymity. In this way, it was possible to reach a wide range of respondents, ensuring the representativeness and reliability of the study. The data collected in this study is significant for understanding how e-crime affects the digital economy and what preventive measures should be taken.

4. RESULTS AND DISCUSSION

Different age groups, genders and professional fields were represented in the survey. This diversity ensured that the findings were representative of the wider population. Based on the data of the conducted survey, in which 413 respondents participated, it can be said that Lithuanian residents are familiar with the threats of e-crimes and their impact in the digital economy at various levels. About 91% of respondents use the Internet at least once a day, and the most common areas of Internet use include communication, leisure activities, and reading news, reflecting observations that active Internet use is associated with increased vulnerability. The survey revealed that:

- Respondents' attitude to the concepts of e-crimes shows that most of them consider e-crimes to be any criminal acts committed using digital technologies. This shows that it is important for educational programs to maintain a broad approach to e-crime, covering its various forms and consequences, in order to ensure that users are well informed and able to respond effectively to potential threats in various scenarios.
- 96% of respondents have directly or indirectly encountered e-crimes, the most common types of crimes being identified as online fraud and identity theft.
- 81% of respondents indicated that they are not or not at all concerned about becoming a victim of cybercrime.
- 89% of participants said they had received no formal training on how to protect themselves from cybercrime.

These results highlight the need for increased public awareness and education programs. As the knowledge about cyber security threats was rated on average by the respondents, the need to strengthen education in this area became evident. The survey also revealed that respondents may overestimate their ability to recognize e-crime attempts, as only 0.39% of respondents indicated that they would not recognize e-crime, which shows the need for improving informative education. Respondents believe that there are shortcomings in the public security infrastructure, especially when it comes to the protection of personal data and education about reliable methods of protection. This is in line with recommendations to strengthen the national cyber security level and public policy. According to the results, it can be said that there is a need to develop and implement various types of cyber security education programs, the purpose of which is to increase public awareness of e-crimes and their prevention, and also to encourage members of the public, especially young people, to participate in cyber security training, which can significantly reduce the number of crimes and increase the overall level of security. These conclusions are based on survey data and are in line with modern cyber security trends in Lithuania.

5. CONCLUSION

1. Based on the literature and global experience, the article analyzed the theoretical aspects of e-crimes. E-crime is a complex problem arising from various factors, including social, economic and technological aspects. In the digital economy, e-crimes are becoming increasingly sophisticated and pose serious risks to both individuals and organizations. Global experience shows that technological advances, dissemination of information and anonymity on the Internet are the main factors contributing to the spread of these crimes. In addition, the ever-changing nature of cyber threats complicates the efforts of law enforcement and security agencies to combat e-crime.

2. During the research, a user survey was conducted in order to assess the resistance of the Lithuanian digital economy to e-crimes. The consumer survey showed that the majority of respondents are young and use the Internet frequently, but their knowledge of cyber risks is limited. This suggests a need for better consumer education and more effective security measures.
3. Based on the conducted research, recommendations were made to strengthen cyber security education and awareness raising, especially among youth and representatives of the business sector. It is also proposed to invest in new technological security measures and to strengthen legal and regulatory measures in order to effectively combat e-crimes. Public-private collaboration and international cooperation are also essential to successfully address cybersecurity challenges in the digital economy.

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Original research

DESIGN OF A DIGITAL MODEL FOR RESERVE ESTIMATION AT THE BLED EL HADBA PHOSPHATE DEPOSIT- BIRELATER, TEBESSA

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Abstract: Enhancing the economic landscape of a nation and elevating societal well-being hinges on the strategic utilization of mineral resources. This study focuses on optimizing phosphate mining in the Bled el Hadba deposit, located in the Bir Elater region of Tebessa. By leveraging geological data and drilling logs, we analyze mineral distribution, structures, and alterations to pinpoint high-yield areas for sustainable exploitation. Additionally, we highlight the transformative impact of data science on mining operations, revolutionizing decision-making processes. Advanced analytical techniques, including modeling and machine learning, enable precise predictions of future performance by considering variables such as ore grade and deposit geometry. The integration of these methodologies not only enhances operational efficiency and profitability but also fosters environmental sustainability. Collaboration between data scientists and geoscience experts facilitates rapid analysis and interpretation of exploration data, propelling innovation in the mineral exploration sector. Our modeling efforts yield spatial layouts depicting grade distributions, laying the foundation for informed decision-making in future exploitation endeavors. This interdisciplinary approach underscores the imperative of synergy between diverse fields, underscoring the potential for collective advancement in mineral resource management.

Keywords: Rational exploitation, exploitation elements, reserves, modelling, data science

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1. INTRODUCTION

The development of the phosphate industry stands as a pivotal pathway towards bolstering economic resilience and fostering sustainable growth. This sector's evolution necessitates substantial investments across various fronts, spanning mining, processing, and transportation infrastructures (Gorman et al.2020; Jowitt, 2021; Mesquita et al. 2021). These investments not only catalyze the modernization of existing infrastructures but also lay the groundwork for robust logistics chains, thereby amplifying efficiency and productivity throughout the value chain. The infusion of capital into mining infrastructure empowers the extraction of phosphate resources with greater precision and efficacy (Verhoeven, 2017; Jooshaki,et al. 2021). Enhanced mining technologies and methodologies streamline extraction processes, optimizing resource utilization while minimizing environmental impact. Moreover, modernized mining infrastructures embody a commitment to sustainable practices, integrating eco-friendly measures to mitigate ecological footprint.

In tandem with mining advancements, investments in processing facilities are indispensable for refining raw phosphate into high-value final products. State-of-the-art processing plants equipped with advanced technologies facilitate the extraction of phosphorus in its purest form, ensuring superior quality and market competitiveness. Furthermore, the modernization of processing infrastructure enhances operational efficiency, driving down production costs and bolstering profitability.

The significance of efficient transportation infrastructure can't be overstated in the context of the phosphate industry. A well-developed transportation network expedites the movement of raw materials from mining sites to mineral processing plants and onward to distribution centers or export terminals. By minimizing transit times and reducing logistical bottlenecks, optimized transportation infrastructure enhances supply chain resilience and responsiveness to market demands (Wang et al. 2017; Salhi,et al. 2023). The ripple effects of investments in the phosphate industry extend beyond its immediate sphere, permeating into other sectors of the economy. The modernization of mining, processing, and transportation infrastructures stimulates economic activity, creating employment opportunities and fostering a conducive environment for ancillary industries. Moreover, the burgeoning phosphate sector serves as a catalyst for broader economic diversification, reducing dependency on traditional revenue streams and fortifying national resilience against external economic shocks. Crucially, the exploitation of phosphate reserves offers Algeria a strategic avenue for economic diversification and resilience-building (Shammas, 1999; Nettour, et al. 2018; Lebdioui, 2020). By tapping into its abundant phosphate deposits, Algeria can forge new revenue streams, reducing reliance on volatile oil markets and promoting long-term economic stability. Diversification of revenue sources not only cushions against external market fluctuations but also fosters a more balanced and sustainable economic framework, underpinned by robust industrial sectors and enhanced competitiveness on the global stage (Chaib, 2016 A; Chaib, 2016 B; Ahi et al., 2023).

Actually, the development of the phosphate industry heralds a transformative journey towards economic prosperity and sustainability. Through strategic investments in mining, processing, and transportation infrastructures, Algeria can harness the full potential of its phosphate resources, fostering inclusive growth, and cultivating a resilient economic landscape for generations to come, see Figure 1.

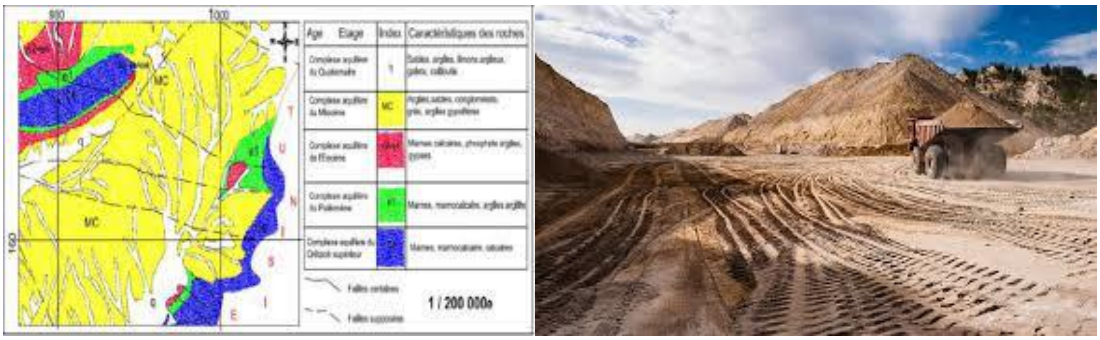

Figure 1. Geological composition of the deposit and quarry opening

2. IMPORTANCE OF PHOSPHATE FOR THE COUNTRY

Phosphorus holds a pivotal position in driving the economic trajectory of Algeria, primarily owing to its scarcity and multifaceted applications spanning across pivotal sectors of the national economy. Its strategic significance not only underscores its criticality but also positions it as a linchpin for bolstering the country's food security paradigm. The focal point of phosphorus extraction lies in the Djebel Onk region within the Wilaya of Tebessa, where substantial resources, estimated at nearly 2 billion tons of phosphates, reside beneath the surface. These resources are efficiently harnessed by SOMIPHOS, an Algerian entity operating under the aegis of FERPHOS (Nettour et al. 2019; Bouaraba, 2022; Boubezari, 2022; Sharma,et 2023).

In the agricultural realm, phosphorus emerges as an elemental cornerstone, playing an indispensable role in augmenting production dynamics. As an integral constituent of phosphate fertilizers, its presence orchestrates optimal yields, thereby assuming a pivotal role in fortifying Algeria's agricultural backbone. With an ever-expanding populace, the imperative to bolster agricultural output looms large, necessitating a concerted effort to ensure phosphorus availability (Allioui, 2023; Balasundram, 2023; Brakni, 2023; Zeboudj 2023). Leveraging its significant phosphate reserves presents Algeria with an opportune avenue to foster a burgeoning local fertilizer production landscape. By charting this trajectory, the nation not only mitigates reliance on costly imports but also catalyzes job creation and propels industrial growth.

The valorization of mineral resources assumes paramount importance, wielding the potential to catalyze a transformative narrative in Algeria's economic landscape. In this vein, phosphates emerge as a globally coveted mineral resource, promising manifold benefits ranging from economic fortification to the amelioration of living standards and the sustenance of sustainable economic expansion. The centrality of phosphorus extends beyond the agricultural domain, permeating into facets such as the fertilizer industry, export dynamics, job generation, investment allure, and economic diversification endeavours.

By harnessing its phosphate reserves adeptly, Algeria stands poised to assert its prominence on the international stage, capitalizing on burgeoning global demand and translating it into substantial export revenue. This strategic pivot not only bolsters the nation's fiscal standing but also underlines its emergence as a formidable contender in the global economic arena (Zeboudj, 2023). Thus, the saga of phosphorus in Algeria embodies not just a mineral resource but a fulcrum for catalyzing holistic socio-economic development, encapsulating aspirations for prosperity, resilience, and sustainable growth on the national and international fronts, Figure 2.

Figure 2. Some phosphate applications

Indeed, fostering the growth of the phosphate industry necessitates substantial investments in mining, processing, and transportation infrastructure. These crucial investments not only facilitate the extraction and processing of phosphate resources but also pave the way for the modernization of associated infrastructure and logistics networks (Salmi, et al. 2021; Khaustova, 2022; Saadia, et al. 2024;). As a result, the ripple effects extend beyond the phosphate sector, positively influencing various other segments of the economy. Algeria stands to benefit significantly from the exploitation of its phosphate reserves. By diversifying its revenue streams through phosphate mining, the nation can mitigate its dependence on oil revenues and shield itself from the volatility inherent in oil price fluctuations. (Carraresi, 2021; Addagada, 2022; Liu, et al.2022)This strategic diversification lays the groundwork for a more robust and resilient economic framework, offering stability and equilibrium amidst external market uncertainties. In essence, the development of the phosphate industry serves as a catalyst for broader economic transformation and sustainability in Algeria.

3. DATA AND METHODOLOGY

The contemporary approach to mining deposit tracing amalgamates diverse geo-scientific technologies, computer modeling prowess, and cutting-edge 3D visualization tools [7, 8]. This sophisticated methodology empowers mining enterprises to finely calibrate deposit exploitation strategies while diligently curbing environmental footprints. Leveraging 3D geological modeling software such as Leapfrog, Gemcom, and Surpac, practitioners craft intricate numerical blueprints of deposits by amalgamating meticulously gathered geological data. These meticulously rendered models offer a panoramic view of mineral dispersion, structural nuances, and alterations, thereby streamlining the pinpointing of high-yield zones earmarked for future exploitation. Such technological arsenals effectively bolster operational efficiencies while concurrently mitigating losses and overheads.

The trajectory of mining deposit tracing has veered towards an integrated approach, harnessing multi-sourced data streams, leveraging avant-garde technologies, and deploying specialized software to fine-tune mining makeovers and pinpoint high-value extraction areas. This harmonized toolset equips mining entities with the acumen to make judicious decisions, meticulously navigating risks, and circumventing adverse environmental ramifications see Figure 3. As prime sources of data, we draw upon the comprehensive deposit profiles

exemplified in Figure 1, complemented by an array of core samples meticulously cataloged in Annex 1.

Through this integrated framework, mining endeavors are poised to transcend conventional limitations, orchestrating a symphony of data-driven precision and technological finesse. By synergizing diverse data streams with cutting-edge software capabilities, mining entities ascend to new echelons of operational efficacy and environmental stewardship, thereby redefining the paradigm of sustainable resource extraction.

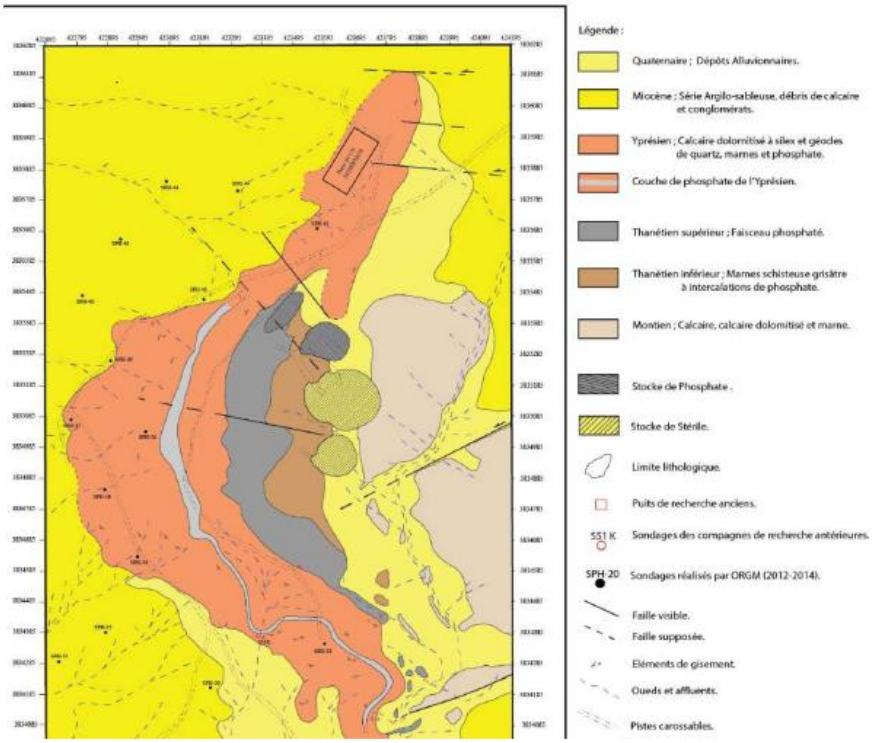

Figure 3. Profile plot of the Bled el Hadba phosphate deposit

4. RESULTS AND DISCUSSION

The dataset under scrutiny delineates the characteristics of a phosphate reservoir nestled within the confines of Bled El Hadba. Amidst its contents, a plethora of information unveils itself, comprising coordinates corresponding to numerous samples and the pinnacle depths reached by the cores. Moreover, the dataset offers intricate insights into mineral compositions, a facet that could ostensibly convolute the visualization process, particularly in the realm of 3D plotting. However, cognizant of the perils of information overload, we adopt a strategic approach, opting to forge a profile that serves as a beacon, illuminating the coordinates of the most auspicious locales ripe for further investigation.

Our analytical journey commences with the utilization of Python as our tool of choice for data visualization. We embark on the transformation of the raw dataset into a CSV format, a maneuver that renders it amenable to manipulation within the Python ecosystem. Upon importation, we proceed to establish a meticulously gridded 2D lattice overlaying the geographic expanse whence the samples were procured. This gridded framework facilitates the

ascertainment of the Z-axis altitude for each point (x, y), alongside the determination of the maximum depth at which phosphate deposits endure. To accomplish this feat, we invoke the prowess of cubic interpolation, a methodological staple renowned for its efficacy in inferring values amidst data lacunae.

In our pursuit of precision, we are compelled to part ways with certain data points that defy interpolation due to informational paucity, thereby engendering the formation of a non-rectangular 3D terrain. To augment interpretability, a judiciously crafted color code is superimposed upon the visualization, elucidating regions harboring the most bountiful reservoirs. This chromatic demarcation serves as a navigational aid, guiding stakeholders towards prospective drilling sites where the promise of ample yields beckons. Through this symbiosis of data-driven insights and computational finesse, we unveil a nuanced narrative encapsulating the latent potential of phosphate deposits in Bled El Hadba, paving the way for informed decision-making and strategic resource allocation, see Figure 4.

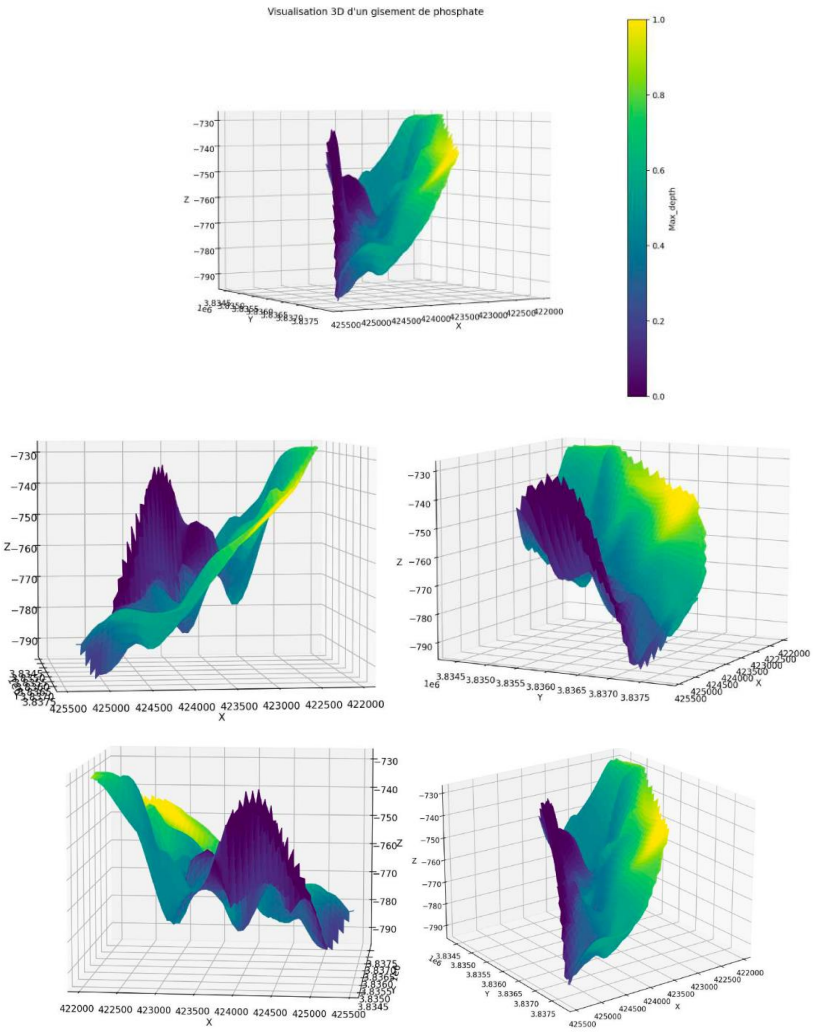

Figure 4. 3D visualization of the deposit in three directions

These findings enable us to pinpoint the most effective strategy for harnessing phosphate reserves and acquiring necessary equipment. However, the importance of economic scrutiny cannot be overstressed, Figure 5. Thus, performing a thorough techno-economic evaluation becomes essential. This research guarantees a harmonious evaluation of both

technical practicability and financial feasibility, streamlining knowledgeable choices in the utilization of phosphate stores and the accompanying infrastructure strategizing . By intertwining technical and economic analyses, this study provides a comprehensive framework for making informed decisions regarding phosphate exploitation and infrastructure development.

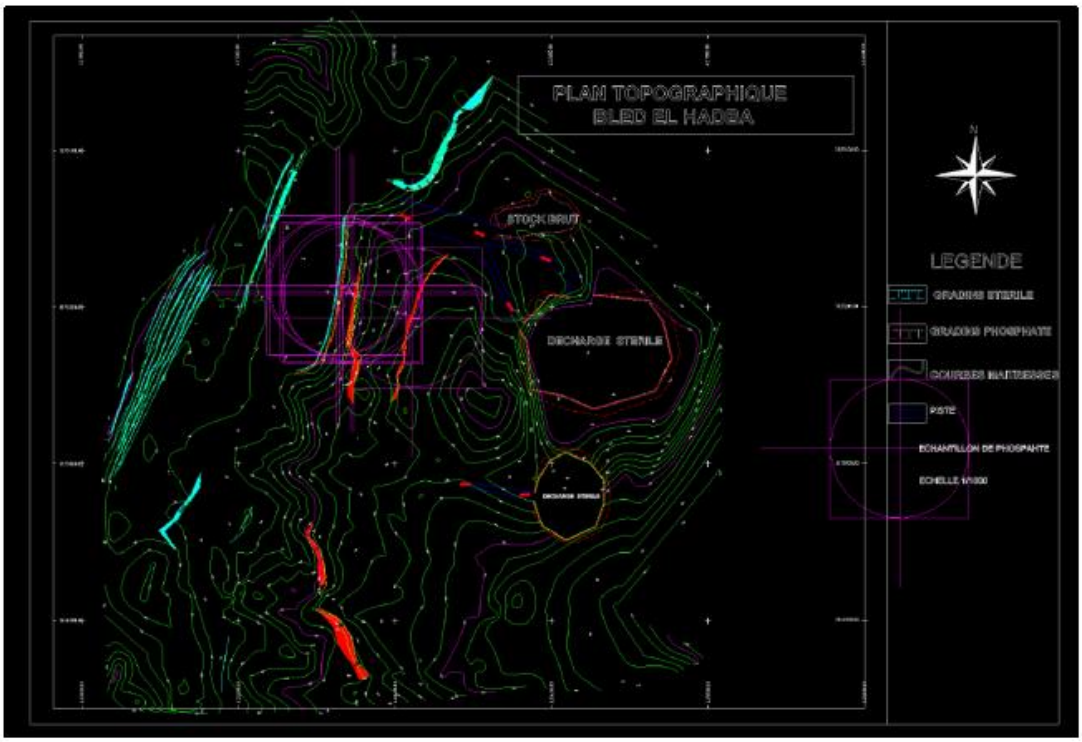

Figure 5. Topographic map of Bled el Hadba deposit

These findings enable us to select the optimal approach for utilizing phosphate reserves and the requisite machinery. Yet, the significance of economic analysis cannot be understated. Consequently, conducting a comprehensive techno-economic assessment becomes imperative. This study ensures a balanced consideration of both technical feasibility and economic viability, facilitating informed decision-making in the exploitation of phosphate deposits and associated infrastructure planning.

5. CONCLUSION

The integration of data science into the mining industry has fundamentally altered how companies make decisions regarding mining operations. These advanced analytical approaches have ushered in new perspectives on efficiency, profitability, and sustainability. Data science enables the analysis of complex variables such as ore grade, deposit geometry, and geotechnical conditions. This translates into more precise planning and efficient extraction activities. By applying modeling techniques and machine learning, mining companies can predict the future performance of their operations. Geostatistical models and simulation methods are utilized to generate detailed 3D models of deposits, facilitating decision-making regarding extraction methods and extraction rates. Moreover, these data help identify and manage potential risks associated with mining, thereby preventing accidents and major disruptions.

In conclusion, the integration of data science into the mining industry has profoundly influenced decision-making regarding mining operations. It has become essential to incorporate this new element into the curriculum of future engineers specializing in mining and materials engineering. Therefore, the École Nationale Supérieure de Mécanique et des Microtechniques (ENSMM) offers seminars introducing the basics of data science (SQL, R language, machine learning, etc.) and opening the door to challenges surrounding these subjects, with the aim of improving existing mining explorations.

The application of data science to mining operations has led to a paradigm shift in the industry's approach to decision-making. These innovative techniques provide mining companies with invaluable insights into their operations, enabling them to optimize efficiency, maximize profitability, and minimize environmental impact. Furthermore, the integration of data science into mining education is crucial for preparing future professionals to navigate the evolving landscape of the industry. By equipping students with the necessary skills and knowledge in data analysis and machine learning, educational institutions play a vital role in shaping the next generation of mining engineers and materials scientists.

Overall, the integration of data science into mining education and practice represents a significant opportunity to enhance efficiency, innovation, and sustainability in the industry. Through collaborative efforts between academia, industry, and government, we can harness the power of data science to address the complex challenges facing the mining sector and create a more prosperous and sustainable future.

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Annexe1

ID	AREA	PROG	X	Y	Z	Max_depth
BEH-CERAD-DH-01	BEH	CERAD	424600	3837224	783,16	61,2
BEH-CERAD-DH-02	BEH	CERAD	424100	3837444	777,46	108,4
BEH-CERAD-DH-03	BEH	CERAD	424200	3837006	782,67	84,4
BEH-CERAD-DH-04	BEH	CERAD	423800	3837289	766,89	123,4
BEH-CERAD-DH-06	BEH	CERAD	423400	3836862	755,26	167
BEH-CERAD-DH-07	BEH	CERAD	423900	3836148	784,04	48,1
BEH-CERAD-DH-08	BEH	CERAD	423000	3836718	748,5	210
BEH-CERAD-DH-09	BEH	CERAD	424600	3837543	775,48	121,4
BEH-CERAD-DH-10	BEH	CERAD	422900	3836127	748,32	148
BEH-CERAD-DH-D19	BEH	CERAD	424968,585	3837184,32	790,83	46,9
BEH-CERAD-DH-D20	BEH	CERAD	423533,538	3835895,93	764,84	78,2
BEH-CERAD-DH-D21	BEH	CERAD	423287,752	3834569,29	768,15	80
BEH-CERAD-SH-P1	BEH	HIST	424551,58	3836497,89	777,4	19
BEH-CERAD-SH-P2	BEH	HIST	423913,4	3835437,25	771,28	33,8
BEH-CERAD-SH-P3	BEH	HIST	425029,26	3836982,23	792,14	13,4
BEH-EREM-DH-01	BEH	EREM	423166,037	3834390,65	750,3	98,9
BEH-EREM-DH-02	BEH	EREM	423162,217	3834797,79	773,82	72,3
BEH-EREM-DH-03	BEH	EREM	422739,862	3834851,05	747,18	99,6
BEH-EREM-DH-04	BEH	EREM	423234,441	3835607,64	756,42	106,2
BEH-EREM-DH-05	BEH	EREM	422838,892	3835688,23	745,58	145,8
BEH-EREM-DH-06	BEH	EREM	423690,373	3836308,61	772,5	85,7
BEH-EREM-DH-07	BEH	EREM	423316,053	3836563,16	757,22	165,2
BEH-EREM-DH-08	BEH	EREM	423750,01	3836767,62	763,52	118,3
BEH-EREM-DH-09	BEH	EREM	424549,004	3836884,44	772,66	63,9
BEH-EREM-DH-10	BEH	EREM	424125,444	3837152,18	775,82	115,7
BEH-EREM-DH-11	BEH	EREM	424508,55	3837344,9	785,6	98
BEH-EREM-TR-01H	BEH	EREM	423796,858	3834387,41	748,293	23,5
BEH-EREM-TR-02H	BEH	EREM	423620,91	3834527,64	755,618	34,5
BEH-EREM-TR-03H	BEH	EREM	423335,159	3834933,77	760,686	31,9
BEH-EREM-TR-04H	BEH	EREM	423874,91	3835580,68	763,904	33,8

BEH-EREM-TR-05H	BEH	EREM	424046,89	3835978,88	769,7	32,9
BEH-EREM-TR-06H	BEH	EREM	424606,485	3836482,91	772,344	12,9
BEH-EREM-TR-07H	BEH	EREM	424781,11	3836656,21	774,274	9
BEH-EREM-TR-54K	BEH	EREM	423410,565	3835190,42	763,388	34,3
BEH-EREM-TR-55K	BEH	EREM	423923,858	3835800,28	769,838	33
BEH-EREM-TR-56K	BEH	EREM	423392,045	3834702,26	756,998	34,2
BEH-ORGM-DH-01	BEH	ORGM				
BEH-ORGM-DH-03	BEH	ORGM	422228,666	3834344,45	729,15	134,7
BEH-ORGM-DH-03-A	BEH	ORGM	422228,666	3834344,45	729,15	209,5
BEH-ORGM-DH-04	BEH	ORGM	422026,843	3834772,48	729,141	194,6
BEH-ORGM-DH-05	BEH	ORGM	422054,657	3835168,99	727,63	168,9
BEH-ORGM-DH-06	BEH	ORGM	422056,39	3835552,37	728,265	
BEH-ORGM-DH-07	BEH	ORGM	422092,351	3835947,81	732,066	
BEH-ORGM-DH-08	BEH	ORGM	422061,599	3836364,53	729,18	
BEH-ORGM-DH-09	BEH	ORGM	422249,863	3836929,51	732,105	
BEH-ORGM-DH-10	BEH	ORGM	422739,084	3837315,32	736,606	
BEH-ORGM-DH-10-A	BEH	ORGM				
BEH-ORGM-DH-20	BEH	ORGM	423224,597	3834207,85	750,986	
BEH-ORGM-DH-21	BEH	ORGM	422737,857	3834289,41	740,196	
BEH-ORGM-DH-22	BEH	ORGM	422501,594	3834679,15	741,734	
BEH-ORGM-DH-24	BEH	ORGM	422415,536	3835322,04	737,494	
BEH-ORGM-DH-25	BEH	ORGM	422450,363	3835712,27	738,409	
BEH-ORGM-DH-26	BEH	ORGM	422584,494	3835899,77	741,445	184,9
BEH-ORGM-DH-27	BEH	ORGM	422589,9	3836303,01	740,937	207,1
BEH-ORGM-DH-28	BEH	ORGM	422724,391	3836505,44	744,292	
BEH-ORGM-DH-29	BEH	ORGM	422759,383	3836893,31	741,1	208,9
BEH-ORGM-DH-30	BEH	ORGM	423130,389	3837051,34	749,317	174,8
BEH-ORGM-DH-31	BEH	ORGM	423408,192	3837435,16	755,81	165
BEH-ORGM-DH-32	BEH	ORGM	423795,66	3837606,67	766,728	142,5
BEH-ORGM-DH-33	BEH	ORGM	423590,195	3834346,74	765,632	82,6
BEH-ORGM-DH-34	BEH	ORGM	422991,137	3834631,18	757,91	
BEH-ORGM-DH-36	BEH	ORGM	422886,564	3834851,87	759,183	
BEH-ORGM-DH-37	BEH	ORGM	422775,395	3835073,74	755,408	94
BEH-ORGM-DH-38	BEH	ORGM	423014,682	3835035,47	774,352	84,2
BEH-ORGM-DH-39	BEH	ORGM	422901,07	3835265,63	757,896	83,4
BEH-ORGM-DH-40	BEH	ORGM	422811,205	3835477,64	750,837	112,1
BEH-ORGM-DH-41	BEH	ORGM	423208,67	3835461,4	767,96	73
BEH-ORGM-DH-42	BEH	ORGM	422935,886	3835661,21	754,409	134,5
BEH-ORGM-DH-43	BEH	ORGM	423081,873	3835847,99	752	121,4
BEH-ORGM-DH-44	BEH	ORGM	423317,038	3835818,65	760,43	91,7
BEH-ORGM-DH-45	BEH	ORGM	423568,674	3835690,28	768,938	66
BEH-SONAREM-DH-27	BEH	SONAREM	423187,612	3835191,88	777,48	96,3
BEH-SONAREM-DH-51	BEH	SONAREM	422934,259	3834369,66	748,57	94
BEH-SONAREM-DH-52	BEH	SONAREM	422792,579	3835280,45	745,41	89
BEH-SONAREM-DH-53	BEH	SONAREM	423829,186	3835819,77	774,28	87
BEH-SONAREM-DH-54	BEH	SONAREM	250,76	3836016,34	753,46	109

BEH-SONAREM-DH-55	BEH	SONAREM	424392,168	3836471,77	770,41	55
BEH-SONAREM-DH-56	BEH	SONAREM	424000,477	3836612,22	774,04	92
BEH-SONAREM-DH-57	BEH	SONAREM	425378,203	3837780,76	783,04	66,5
BEH-SONAREM-DH-58	BEH	SONAREM	424946,195	3837132,32	792,95	52

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Original research

SELECTION OF CUTTING INSERT FOR LONGITUDINAL TURNING OF UNALLOYED STEEL USING ROBUST DECISION MAKING

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Abstract: Cutting tool is a very important element of machining production system. It is primarily responsible for material removal in the form of chips, but also significantly affects multiple machinability characteristics, surface finish, attainable dimensional accuracy, productivity and costs. As for a given machining operation there is a number of alternative cutting tools and inserts from many manufacturers, each characterized by a unique set of characteristics, the selection of a particular cutting tool can be very complex task, yet solvable within the framework of multi-criteria decision making (MCDM) methodology. This study is focused on the development of an MCDM model for selection of the most suitable cutting insert for medium machining of unalloyed structural steel. The model was developed by available information, catalogues of cutting tool manufacturers and machining estimations, and consisted of fourteen alternative cutting inserts from eight well-known cutting tool manufacturers and seven criteria. Initially, the assessment and ranking of alternative cutting inserts was derived by the six multi-criteria decision making (MCDM) methods, however, due to ranking inconsistency, the application of the robust decision making rule was adopted for solving the cutting insert MCDM problem.

Keywords: cutting insert, MCDM, turning, robust decision making rule.

1. INTRODUCTION

Market openness and global competition are a reality for many production companies. In order to be recognized and accepted on the market, they must offer customers products at an affordable price, in the appropriate quantity, and in addition produce them according to strict and multiple quality requirements. These multiple issues, but also numerous uncertainties and risks regarding inputs, such as prices and availability of resources, electricity, availability and cost of quality workforce, technological changes and existence of overall stable business conditions, create great challenges for production companies.

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In order to increase competitiveness, production efficiency, rational use of all available resources, handle environmental issues and solve the previous challenges, the management of production companies considers numerous strategic decisions that are implemented at different hierarchical levels. Monitoring of currently used production technologies, selection and introduction of more technologically advanced production processes, procurement and renewal of machinery, analysis and introduction of alternative tools and accessories, optimization of production process parameters, analysis of alternative technological procedures, plant layout selection, process monitoring, tool condition monitoring, etc., are only some of the strategic measures for improving the business success of production companies.

Regarding the turning technology, which is the oldest and at the same time still one of the most widely used traditional method of material processing, practically all individual elements of the production system can be analysed with the aim of improving the efficiency of processing, taking into account numerous performances including productivity, costs, quality, ecological aspects etc. Since plant layout design can have significant impact of production system performance, İç (2012) proposed the use of experimental design approach using TOPSIS method for evaluation of 18 alternative plant layouts with respect to six criteria. Singh et al. (2011) proposed a general methodology for evaluation and selecting of the best feasible process technology by using graph theoretic approach and four main groups of criteria related to quality, cost, technical capability and production. A multi-objective decision-making approach for machining process planning optimization was proposed by Lv et al. (2020). It was concluded that optimized machining process plans can result in production cost savings, reduction of environmental impact, as well as improvement of product quality. Rojek et al. (2021) developed an intelligent AI based system for supporting technological process planning in machining. The advantages of the presented concept included the use of a real data from industry, receptivity, fast computation time, and high efficiency. István et al. (2022) addressed the problem of selection of optimal carbide insert by performing an experimental investigation. Carbide inserts evaluation included the assessment of machining times and the service life of inserts with respect to used machining parameters, and the purchase price of the inserts. Madić et al. (2015) applied WASPAS method for evaluating of different cutting inserts for aluminium turning with respect to allowable machining intervals and cutting inserts costs. The AHP and TOPSIS methods were used by Patel et al. (2012) for assessment and evaluation of different cutting tool insert geometries. Taka et al. (2017) conducted a turning experimental study and applied SAW and WPM methods so as to determine which cutting tool insert is the most favourable choice, regarding surface finish, for each of the three workpiece materials. Petković et al. (2017) applied WASPAS method for the analysis and assessment of workpiece-cutting tool material combinations with respect to three machinability indicators, such as tool wear rate, specific energy consumption and surface roughness. Given that monitoring and prediction of tool wear state have significant effects on turning performance, Zhuang et al. (2021) developed a digital twin-driven system for turning process simulation. To avoid unnecessary unfinished parts, waste of resources and increase in production time, Bazaz et al. (2021) proposed a digital twin for the estimation of tool life in turning based on the use of machine learning models. Kuntoğlu and Sağlam (2021) used five different sensors for monitoring cutting forces, vibration, acoustic emission, temperature and current during turning of AISI 5140 steel so as to secure reliable, robust and consistent machining. Maruda et al. (2020) made a comprehensive analysis of topographies and tribological properties of the machined surfaces turned with the constant set of machining parameters but under different cooling/lubricating conditions. Gariani et al. (2021) applied RSM to optimize cutting fluid concentration ratio, indexable cutting tool material, feed rate and cutting speed with respect to resulting surface roughness and tool flank wear in turning of Ti–6Al–4V. Comprehensive comparison of various sustainable and

conventional cutting fluid strategies based on energy consumption and LCA analysis in machining 15–5 PHSS was performed by Khanna et al. (2022). Goswami and Behera (2021) applied COPRAS and ARAS methods for generation of decision rules upon which alternative green cutting fluids were evaluated with respect to cost, environmental impact and quality. Criteria weights were determined with the analytic hierarchy process (AHP). Trung et al. (2022) applied combination of PIPRECIA and FUCA methods for solving MCDM problems, i.e., selection of a new lathe and selection of used lathe. A comprehensive MCDM approach for evaluation of alternative CNC machine tools with respect to seven main and thirteen sub-criteria was proposed by Sahin and Aydemir (2022). In order to handle uncertain and incomplete knowledge and information Lata et al. (2021) applied a fuzzy TOPSIS approach for the evaluation and selection of a CNC lathe.

Machining parameters have a dominant influence on cutting mechanics and associated physical phenomena that occur during the actual cutting process. This in turn is reflected multifold on a number of performances from different categories such as quality, cost, productivity, reliability, environmental impact, etc. Therefore, special importance in research community and industrial practice is given to analysis of parameter effects and parameter optimization with respect to different performance characteristics. In essence, for turning process parameter optimization two main approaches can be distinguished: modeless and model-based approaches. The first approach is usually based on the application of Taguchi's robust design methodology (Kumar et al., 2018; Dutta & Narala, 2021; Jadeja & Zala, 2021; Vijay HamaSur & Abdalrahman, 2023) and its hybridization with other methods, such as PCA, GRA, utility concept, etc., for handling multi-response optimization problems (Bagal et al., 2019; Viswanathan et al., 2020; Sristi et al., 2022; Dragičević et al., 2023). Likewise, a number of MCDM and fuzzy MCDM methods are being proposed for determining optimized turning parameters with respect to multiple criteria of different relative importance (Prakash & Krishnaiah, 2017; Thien et al., 2021; Chowdhury et al., 2023; Haoues et al., 2023). While the application of the Taguchi method can reveal certain near optimal turning parameter combinations, that were not previously included in the experimental matrix, the application of MCDM methods determines the most favourable (optimal) turning parameter combination from the previously known set of alternative parameter combinations. On the other hand, the second approach is based on constructing mathematical relationships between process inputs, such as depth of cut, cutting speed, feed rate, tool nose radius, etc., and process outputs, such as MRR, surface roughness, tool life, costs, electrical energy consumption, etc. These mathematical relationships are usually determined based on analytical, numerical and/or empirical studies via development of different models. In addition, with the integration of these models with optimization algorithms (classical or metaheuristics), different single and multi-objective optimization problems were solved (Horváth & Drégelyi-Kiss, 2015; Chabbi et al., 2017; Kowalczyk, 2018; Prasanth et al., 2021).

From the literature review one can observe that various methods were applied at the micro and macro level, with the ultimate aim to contribute to a greater or lesser extent to the overall improvement of the production system. Considering that the cutting tool is the main carrier of processing in the turning process, on which a number of process performances depend, the aim of this study is the analysis and assessment of alternative cutting inserts for medium machining of unalloyed structural steel. To that end, based on available data and machining estimations, the cutting insert MCDM model was developed with 14 alternative cutting inserts from 8 well-known cutting tool manufacturers which were assessed with respect to 7 criteria. In order to overcome ranking inconsistency due to application of different MCDM methods the application of the robust decision making rule was adopted.

2. SELECTION OF A CUTTING INSERT: MCDM MODEL

During machining, the cutting tool removes a layer of material from the workpiece in the form of chips while forming machined surface. As a key component in the turning production system, it significantly affects the quality of machined surfaces, dimensional accuracy, productivity and economics (Radovanović, 2002; Zhuang et al., 2021). Due to high strain and stress rates during machining, occurrence of high cutting forces and temperatures in the cutting zone, friction in the contact zones of the cutting tool and the workpiece, cutting tools should have high hardness (and ability to retain hardness at higher temperature), good wear resistance and high strength and toughness (Radovanović, 2002). Considering the large number of cutting tool manufacturers, alternative types of cutting tools and variety of cutting tool characteristics and properties, there is a need for a careful selection of cutting tool for a specific machining application.

The MCDM problem of cutting insert selection is related to the following case study. The workpiece material is C45E unalloyed structural steel, annealed, with hardness of 190 HB and tensile strength of 650 N/mm^2. The available machine tools are small to medium CNC lathes with the motor power of up to 25 kW. The cutting tool is a toolholder PCLNR 3225P 12 (cutting edge angle of κ_r = 95° and rake angle of γ_{oh} = -6°) with a rhombic shape C-style (point angle of 80°) negative double-sided insert for medium machining with the cutting edge length of l = 12 mm (Figure 1). Medium machining implies medium operations to light roughing, and wide range of cutting depth and feed rate combinations. Good machining conditions (continuous cuts, high cutting speeds, pre-machined workpiece, excellent component clamping, small overhangs) are assumed. Insert grades with wear resistance, corresponding to ISO grades range of P01-P20, are consequently selected.

Figure 1. One of alternative cutting inserts: Pramet CNMG120408E-SF
(nose radius r_ε = 0.8 mm, rake angle of γ_{oi} = 14.5°)

Based on the available information, catalogues of tool manufacturers and estimation of maximum cutting power for MCDM cutting insert model definition, a large number of different cutting inserts of renowned world manufacturers of cutting tools were selected, such as: Achteck, Pramet, Iscar, Kennametal, TaeguTec, Walter, Widia and ZCC Cutting Tools. The anonymized alternative attributes are given in Table 1. As could be observed the developed MCDM model consisted of 14 alternative CNMG cutting inserts with respect to 7 criteria such as: rake angle γ_{oi} (°) – C_1, nose radius r_ε (mm) – C_2, allowable feed range f (mm/rev) – C_3, allowable depth of cut range a_p (mm) – C_4, allowable cutting speed range v (m/min) – C_5, maximal achievable material removal rate Q (cm^3/min) – C_6 and price C (EUR) – C_7.

Table 1. MCDM model for selection of CNMG cutting insert

Cutting insert	C_1	C_2	C_3	C_4	C_5	C_6	C_7
1	16.0	0.8	0.24	2.90	96.0	493.9	5.00
2	16.0	1.2	0.36	2.60	144.0	695.5	5.00
3	14.5	0.8	0.18	2.20	144.0	253.8	12.39
4	14.5	1.2	0.20	1.80	138.0	289.8	12.39
5	11.0	0.8	0.35	5.00	85.0	563.8	15.43
6	11.0	1.2	0.42	4.70	85.0	676.5	15.43
7	0.0	0.8	0.30	4.60	95.0	701.0	11.06
8	6.0	0.8	0.30	4.30	85.0	625.0	11.06
9	20.0	0.8	0.39	4.70	85.0	757.0	11.06
10	12.0	0.8	0.23	2.5	240	588	9.61
11	15.0	0.8	0.22	4.4	88	816	15.10
12	28.0	0.8	0.18	8.10	85.0	790.0	11.06
13	15.0	0.8	0.20	3.20	55.0	605.0	6.50
14	15.0	1.2	0.40	3.20	110.0	907.0	6.50

From the aspect of cutting mechanics and machining conditions, higher values of rake angles and nose radius are more preferable. Likewise, the possibility of choosing a large number of cutting parameter combinations requires a greater range of variation of main cutting parameters, i.e., depth of cut, cutting speed and feed rate. Therefore, all considered criteria in the MCDM model are criteria of maximization type, while only cutting insert price is the minimization criterion, i.e., lower attribute values of alternatives are preferred.

Relative significance of criteria from the proposed turning MCDM model were determined using the geometric mean method of the AHP and the Saaty's nine-point preference scale (Saaty, 1980), while the consistency check of criteria weights was also performed. For random index value of 1.32, consistency ratio value of 0.06 was obtained. Therefore, one can argue that there was no contradiction in the judgments made in pairwise comparison of criteria. Relative significance of considered criteria was assessed by determining criteria weighting coefficient values as shown in Table 2.

Table 2. Assessment of criteria relative significance

Criterion	C_1	C_2	C_3	C_4	C_5	C_6	C_7
Weight coefficient	0.048	0.04	0.094	0.134	0.094	0.234	0.357

As could be observed from Table 2, price of the cutting insert is the most significant criterion, followed by the possibility of cutting insert to achieve higher MRR values. The relative significance of main cutting parameters was assessed similarly, although somewhat more importance was given to the depth of cut, since wider ranges of this parameter enable greater flexibility in terms of defining the technological procedure, particularly in the case of multi-pass turning operations. Finally, the geometry of the cutting insert is given the least importance.

3. RESULTS AND DISCUSSION

Initially, for solving the defined cutting insert MCDM model for medium machining of unalloyed structural steel different decision rules were generated and applied for ranking generation. Actually, six MCDM methods were applied: the Additive Ratio ASsessment (ARAS), the COmplex PRoportional ASsessment (COPRAS), the Multi-Objective Optimization by Ratio Analysis (MOORA), the VIšeKriterijumska Optimizacija i kompromisno Rešenje (VIKOR), the Technique for the Order Preference by Similarity to Ideal

Solution (TOPSIS) and the Weighted Aggregated Sum Product ASsessment (WASPAS). Kendall's (tau-b) rank correlation coefficients, estimated for assessment of correlations of the final rankings obtained using aforementioned MCDM methods are given in Table 3.

Table 3. Kendall's tau-b rank correlation coefficients of cutting insert rankings

	ARAS	COPRAS	MOORA	VIKOR	TOPSIS	WASPAS
ARAS	1	0.516484	0.56044	0.384615	0.428571	0.450549
COPRAS	0.516484	1	0.868132	0.868132	0.868132	0.846154
MOORA	0.56044	0.868132	1	0.824176	0.868132	0.758242
VIKOR	0.384615	0.868132	0.824176	1	0.868132	0.758242
TOPSIS	0.428571	0.868132	0.868132	0.868132	1	0.758242
WASPAS	0.450549	0.846154	0.758242	0.758242	0.758242	1

As could be observed from Table 3, stronger positive dependence/concordance between final rankings of COPRAS, MOORA and TOPSIS are evident, while the lowest degree of association of the ranks determined by the ARAS method and other MCDM methods is pronounced. As discussed by Zavadskas and Turskis (2010) the ranking inconsistency has root cause in specific properties of each MCDM method including different selection of the best solution, different use of criteria weights, attribute normalization (scaling) and introduction of additional parameters. Although the overall average value of Kendall's tau-b is 0.757, proving a positive correlation among the cutting insert ranking determined by the applied six MCDM methods, the analysis of obtained rankings revealed certain level of ranking inconsistency. For example, ARAS, MOORA and TOPSIS methods assessed cutting insert 14 as the best choice, while COPRAS, WASPAS and VIKOR methods assessed cutting insert 2 as the best choice. Similarly, the third best choice is cutting insert 1, as determined by four MCDM methods (COPRAS, VIKOR, TOPSIS and WASPAS). At the same time ARAS method ranked this cutting insert as 11th, while it obtained 5th ranking as per MOORA method. ARAS and MOORA methods determined cutting inserts 9 and 12 as the third ranked alternative, respectively. Therefore, in order to overcome ranking inconsistency and facilitate the decision-making in the present study the robust decision-making rule (RDMR) was adopted for assessment and ranking of cutting inserts. The main idea of the RDMR is to combine theoretical backgrounds of different MCDM methods with the Taguchi's signal-to-noise (S/N) ratios from robust quality engineering, which is estimated with respect to the utility function values of each considered MCDM method, to yield a more robust, comprehensive and objective basis for decision making (Madić et al., 2022; Petrović et al., 2018).

The rankings of alternative cutting inserts obtained after generation of the RDMR are displayed in Figure 2. It can be observed that the cutting insert 14 is the first-placed alternative, followed by cutting insert 2 and cutting insert 12, which was ranked as third. Hence, the most inexpensive cutting inserts with maximal allowable depth of cut range and MRR, with intermediate rake angle and nose radius of 1.2 mm are found to be best compromise solution for medium machining of unalloyed structural steel. It is interesting to note that according to RDMR cutting insert 12 is ranked third, while only MOORA method ranked it as a third alternative. Perhaps an even better example showing the idea of RDMR is ranking of cutting insert 7. Namely, this cutting insert is ranked 9th by the RDMR, although it was ranked 8th by all MCDM methods except WASPAS method which recognized it as the least preferred cutting insert. Cutting inserts 4 and 3 are the least preferred for this machining application having penultimate and the last ranking of all cutting inserts. These quite expensive cutting inserts from single manufacturer have the narrowest allowable depth of cut and feed ranges and lowest resulting MRR, resulting in being ranked last.

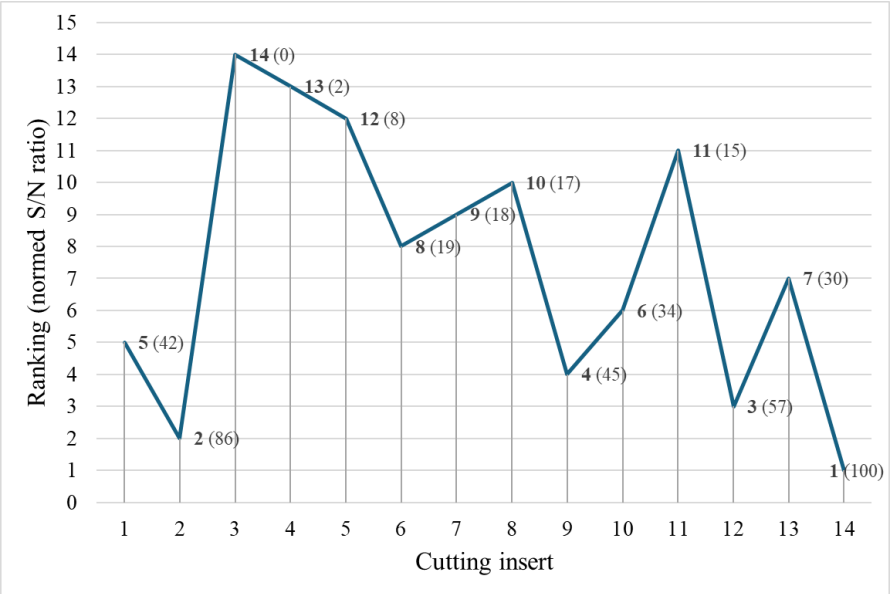

Figure 2. Ranking of alternative cutting inserts by RDMR

4. CONCLUSION

The abundance of cutting tools and inserts with different set of unique characteristics creates additional challenges for production planners when selecting the most suitable one for a particular machining job. Given that the cutting tool is one of the most important elements of the machining production system and that inadequate selection may deteriorate machining quality, increase costs, decrease productivity and overall machining efficiency, one can argue that it is necessary to make comprehensive assessment of multiple alternative cutting tools and inserts with respect to different criteria. In that regard, the main focus of the present study was development of an MCDM model for the selection of the most suitable cutting insert for medium machining of unalloyed structural steel. On the basis of applied methods, AHP, six different MCDM methods and RDMR, obtained results and performed analysis, the following conclusions can be drawn:

- Based on analysis of Kendall's tau-b rank correlation coefficients it was observed that when applied to the problem of cutting insert selection different MCDM methods show inconsistency in ranking which may affect indecisiveness and fickleness of decision makers and additionally complicate the final decision making.
- The applied RDMR ensures ranking of alternative cutting inserts with the highest level of ranking consistency with respect to applied MCDM methods. A more robust and objective approach for cutting insert selection problem would be achieved by including a larger number of MCDM methods and performing of sensitivity analyses with different set of criteria weights.
- It is believed that the developed MCDM model and presented solution approach may serve as an example for decision making related to cutting insert selection for other machining operations and processes.
- Finally, it has to be noted that conclusions drawn may change in case of availability of real empirical machining data or the inclusion of other criteria such as cutting insert manufacturing reputation, delivery time, surface quality, tool life, etc.

Inclusion of other criteria, opinions and attitudes of a large number of experts, additional MCDM methods, and fuzzy attributes can be in the focus of the future research.

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LEVERAGING KNOWLEDGE MANAGEMENT FOR ADVANCING INNOVATIVE THINKING IN THE BANKING SECTOR: INSIGHTS FROM SOUTH AFRICA

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Abstract: Knowledge management is considered as one of the most important factors in ensuring sustainability within organizations, especially in the banking sector. Since knowledge management is an integral part of managerial activity, it is imperative that organizations adopt knowledge-driven culture within which innovations can be incubated. An organization where knowledge management is used to drive innovation is better positioned to create a competitive advantage for itself and to ensure that it achieves a sustainable value creation for its survival. The purpose of this study was to identify key attributes relating to knowledge management that the banking sector can leverage on, in order to inculcate the innovation culture and allowing banks to acquire competitive advantage. For this study, a positivistic research paradigm by means of a quantitative research methodology was undertaken, using a sample from respondents in the banking sector and testing hypotheses through a structured measuring instrument. Based on the empirical study, it was determined that the banking sector applied specified concepts to embrace an innovation culture. These concepts included leadership initiatives and innovation competitiveness. It was concluded that leadership initiatives appeared to be the most important critical factor in driving innovative knowledge-driven culture.

Keywords: Innovation, knowledge management, leadership initiatives, innovation competitiveness.

1. INTRODUCTION

Innovation is considered a key driver for long-term success of organizations in the current competitive markets (YuSheng & Ibrahim, 2020), and knowledge management has significant positive effects on innovation capability (Edeh et al., 2022). It is the growing realization that knowledge is an essential resource for organizations to retain sustainable competitive advantages (Easa, 2012), therefore the main advantage of implementing knowledge management is that organizations could better manage their knowledge and be more successful to face challenges in their work environment (Sofiyabadi & Valmohammadi, 2020).

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An organization where knowledge management is used to drive innovation is better positioned to create a competitive advantage for itself and to ensure that it achieves a sustainable value creation for its survival (Francis et al., 2012; Yen, 2013). Knowledge management can be said to make a distinctive contribution towards the development of a sustainable competitive advantage (Rahimli, 2012), as it helps to maintain new product creation, innovation and organizational performance (Meihami et al., 2014). It has been established that knowledge management plays a pivotal role in the conversion of learning capabilities and extracting core competencies from employees by enabling organizational learning and resource development processes (Gjurovikj, & Center, 2013). Thus, knowledge management provides a knowledge-driven culture (Nawab et al., 2015) within which innovations can be incubated (Hakanson et al., 2011). As Du Plessis (2007) argue, innovation is extremely dependent on the availability of knowledge and therefore the complexity created by the explosion of richness and reach of knowledge has to be recognized and managed to ensure successful innovation.

This study seeks to identify key attributes relating to knowledge management that the banking sector can leverage on, in order to inculcate the innovation culture and allowing banks to acquire competitive advantage. There is scant research to show that the banking sector across South Africa is using knowledge management as a strategic tool to drive an innovation culture. The study therefore focuses on knowledge management as a tool that can be used to enhance innovation in the South African banking sector. Hence the main question guiding this study is: *How knowledge management can assist to create an innovation platform in the banking sector?*

2. RESEARCH OBJECTIVES

Considering the aforementioned main research question and the study's focus, the primary and secondary objectives are outlined in the following sections.

2.1. Primary Objective

The primary objective of the study is to establish what tools can be utilized in ensuring that knowledge management is adequately administered to cultivate an innovation culture in the banking sector.

2.2. Secondary Objectives

In order to achieve the primary objective of this study, the following secondary research objectives are identified:

- To provide a comprehensive literature overview regarding enabling factors of knowledge management.
- To establish a connection between knowledge management and innovation culture.

3. LITERATURE REVIEW

Since this study is focusing on knowledge management in the banking sector linking it to innovation, and ultimately innovation culture, the following sub-sections elaborate on these concepts.

3.1. Knowledge Management and Innovation in the Banking Sector

In the current competitive economy propelled by knowledge, the capacity of organizations to use innovative technology and to adapt to new organizational changes plays a key role in establishing industrial leadership and enhancing their competitiveness (Gyensare & Asare, 2012; Spanellis et al., 2021). For the banks to be competitive in the current economic landscape, they must have the ability to integrate, build and reconfigure their internal and external competencies to address ever-changing environments in the information technology space. This would mean, therefore, as the banks possess complementary capabilities and non-substitutable resources, it would be beneficial for the banks as they would be able to respond to market conditions that influence the bank's innovative capabilities (Cheng et al., 2013). Traditional innovation literature suggests that organizations innovate by getting new and/or improved products to the market. Nevertheless, in a service providing institution, such as a bank, the product is the process (Gyensare & Asare, 2012).

Musolesi and Huiban (2010) view knowledge management as supporting innovation as knowledge management contributes towards the generation of new ideas and ensuring that the organization's thinking powers are exploited optimally. Consequently, according to Francis, et al., (2012), organizations that invest substantially in technology strengthen their competitive advantage, and innovation may present new business opportunities. Knowing how to do things effectively and efficiently in ways that other organizations cannot duplicate is a primary source of profit and competitive advantage (Gyensare & Asare, 2012). Knowledge management is seen as a management function that creates and manages its flow in order to ensure effective use of this knowledge for the sustainable benefits of the organization (Dossa & Kaeufer, 2014), hence knowledge management systems have become one of the fastest growing areas of corporate sector (Nawab et al., 2015).

Information technology (IT) has made it possible for banks to store information, as this has become an important tool to facilitate information sharing and assist in enhancing innovation. New product developments and service offerings are incorporated into the process of change, as this forms an integral part of organizational learning and employee expertise (Elche-Hotelano, 2011). This is consistent with the work of Yen (2013) that highlights the importance of human capital as a key feature contributing towards innovation in the service industry. Most organizations are putting an effort into improving technology transfer activities amongst their employees, and into developing means of measuring performance in innovation activities and innovation impact on the organization's overall performance (Alessandrini et al., 2013). It is important to understand employee's competencies, as they form an integral part of the knowledge management strategy, and to understand how they may contribute to sustainable organizational productivity and knowledge retention (Yen, 2013).

According to Yen (2013), innovations are tied to existing knowledge, different aspects of capital and an organizational generic ability to innovate. In an organization where there is a diversity of skills and employees have the ability to acquire new skills, existing paradigms are challenged, and new norms developed. This ability has a potential to transform existing knowledge into new knowledge. When there is an information overlap, employees are better able to make connections and associations between different types of knowledge, which leads to creation of additional new knowledge.

3.2. Determinants of Innovation Culture

The development and introduction of an innovation culture in an organization is critical in the current competitive environment. Factors influencing this culture may both be internal as

well as external activities (Chen & Huang, 2009). Growing complexities in competitive environments compel organizations to persistently search for new innovative ways to ensure their survival. The content and methodology that get to be applied in order to inspire an innovation culture are unique on service activities, as compared to manufacturing activities (Elche-Hotelano, 2011). Innovation has an impact on the organizational processes which facilitate improvements of technology and services in an organization (Williams & Woodson, 2012). For innovation to be effective it must influence economic growth, both in the manufacturing sector, as well as in the service sector (Love et al., 2010; Alessandrini, et al., 2013). The ever-changing customer needs have dictated the complex nature of innovation, which has led to competitive pressure and rapid change in technology (Yen, 2013).

Dossa and Kaeufer (2014) argue that financial institutions have a pivotal role to play in society to create sustainable financial innovations, while Yen (2013) reasons that financial performance should be closely tied to innovative capabilities and sustainability, which should be demonstrated on the organization's return on asset (ROA) and return on equity (ROE), which are the measures of organization financial performance. It is for such arguments that Ponte and Cullen (2013) maintain that new ideas should be adapted to existing realities for innovation to manifest. The drivers of innovation strategies would involve decisions made by the management in stimulating interest to invest on the type of innovation initiatives that fit the culture of an organization (Eiriz et al., 2013) for them to stimulate organization financial performance. For this study, such innovation initiatives include leadership initiatives and innovation competitiveness.

3.2.1. Leadership Initiatives

When good corporate governance manifests in an organization, knowledge intermediaries can be created and mutual connections forged (Francis et al., 2012). Knowledge intermediation is the process in which one organization assists in connecting two or more of their clients with a view to combining their respective knowledge and capabilities in innovative ways (Scarso & Bolisani, 2011). Recognition of knowledge intermediaries for technological and business process innovation reinforces the views that a number of variables are connected through social, industrial, scientific and technological networks (Cantù et al., 2015). By embracing good governance, an organization is assisted in being able to determine innovative projects that require long-term investments, taking into account uncertainty as to the delivery time and the amount of capital required, and the fact that the probability of eventual success is not guaranteed (Sotiriadis & Van Zyl, 2013).

According to Nawab et al. (2015), leadership is considered as the support of top management for the achievement of knowledge management related activities. Leadership is an important critical success factor of knowledge management and is also helpful in successful knowledge management implementation. As the knowledge management is a complex activity so it needs management leadership and support to achieve the highest level of organizational performance (Slavković & Babić, 2013). Singh (2008) opines that the productivity of an organization depends to a larger extent upon management of valid knowledge through suitable styles of leadership, and the role of leader in managing information and knowledge is accomplished through technology and social networks, therefore knowledge leadership is based on relationship building, with a need to constantly network, listen and act on information received from others. Similarly, Kangas (2009) indicates that while leaders across all the levels of organization have unique and important role to play in managing knowledge, it is particularly important for executive management to be involved in knowledge-sharing processes which in turn will enhance value and help increase an organization's competitive advantage.

Donate and de Pablo (2015) investigated the mediating effect of knowledge management practices in the relationship between knowledge-oriented leadership and innovation performance, and the results show that the existence of leadership initiatives encourages the use of knowledge management practices, as a result, an organization is able to improve its performance in product innovation. For the banking sector, leadership initiatives included elements such as learning and knowledge transfer, knowledge culture development, talent development and succession planning.

3.2.2. Innovation Competitiveness

Knowledge management is positively related to organization's innovativeness (Chen et al., 2010) where the availability of knowledge creates a good platform for innovativeness (Šajeva & Jucevičius, 2008). Increasing the level of innovativeness in an organization is importantly dependent upon appropriate working and behavior of management, which must create and maintain appropriate conditions for innovative working and behavior of organization as a whole and its employees (Nedelko & Potocan, 2013). Strategic Management is needed in preparing technology readiness of banks in customer-focused services, and addressing the readiness toward innovation will depend on the readiness of the employees in the banking sector (Kamaludin & Purba, 2015). Hence, management attitudes towards innovativeness are the foundation for designing and development of innovative working in all types of organizations (Nedelko & Potocan, 2013).

The abundance of knowledge created by the complexities in the innovation processes has to be recognized and managed systematically (Creswell, 2009). Training and development is an indispensable strategic tool for enhancing employee performance, and there is a strong relationship between training and development, employees' performance, and competitive advantage (Falola et al., 2014), as well as the level of innovative working and behavior of all employees (Nedelko & Potocan, 2013). Hence, Sedziuviene and Vveinhardt (2010) maintain that knowledge is the means, which are necessary to possess in order to improve, develop and maintain business processes, enabling fast and appropriate responses to changing environment conditions.

The world is transforming from the traditional systems into high end technology; therefore, the improvements of banking industry's technology must receive top priority in a manner that strengthens bank's internal management (Purba, 2015). In order to be able to seek innovations on every step in the organization, one must have holistic understanding of innovations, this is especially important for management, since it must create conditions for innovativeness for all organizational members (Nedelko & Potocan, 2013). Integration of knowledge ensures that knowledge required for innovation and new development is readily available and accessible (Gyensare & Asare, 2012), thus ensuring the flow of knowledge used in the innovation process (Musolesi & Huiban, 2010). Elements forming the organizational context as the determinant of company innovativeness, according to Szczepańska-Woszczyna (2018) are organizational structure, strategy and organizational culture. For the banking sector, innovation competitiveness included elements such as education and skills development, technological readiness, supportive environment and enabling innovation culture. From the above arguments of leadership initiatives and innovation competitiveness, the following hypothesis is posed:

H_1: There is a significant relationship between *Leadership Initiative* and *Innovation Competitiveness*.

4. RESEARCH METHODOLOGY

For this study, a positivistic research paradigm by means of a quantitative research methodology was undertaken. A descriptive and exploratory research design approach was employed. The purpose of a descriptive study was to provide a vivid picture of a situation or person or show how things are related to each other and thus describing the perceptions of respondents regarding the influence of leadership initiatives (LI) on innovation competitiveness (IC). Exploratory factor analysis (EFA) is generally regarded as a technique for large sample sizes (N), with $N = 50$ as a reasonable absolute minimum (de Winter et al., 2009), however, Yurdugül (2008), suggest that a sample size of 100 respondents is adequate for an unbiased estimator of coefficient alpha. Based on this information, the study had a target sample of greater than or equal to 100 respondents. A sample of 107 respondents was received and only 100 questionnaires were completed in full making response rate of 93%. The sample was made up of team leaders and middle management as well as innovation champions from 29 branches of banks in the Eastern Cape Province, South Africa. The responses obtained from the respondents were analyzed and compared with the information gathered in the literature review.

For data analysis, the study used advanced and inferential statistics such as exploratory factor analysis, Cronbach's alpha coefficients, Pearson Product Momentum Correlation and One-sample t-test. For Cronbach's alpha, values above 0.7 are generally considered acceptable and satisfactory, those above 0.8 are usually considered quite good and those above 0.9 are considered to reflect exceptional internal consistency (Mohajan, 2018).

To assess face and content validity of the measuring instrument, expert judgement was obtained from researchers in the field of business management, social responsibility and statistics and a pilot study was conducted among 10 respondents to pre-test the questionnaire. Construct validity was assessed using exploratory factor analysis (EFA) to determine which items load onto which factors with a cut-off point of 0.5 (Osborne, 2015). The non-random sample method was used as the respondents for this study were selected on the strength of their experience as well as the role they play to influence innovation and knowledge management in their organization.

5. RESULTS

The data was processed using Microsoft Excel spreadsheets, and analysis with StatSoft STATISTICA. The following sections elaborate on the empirical results of the study.

5.1. Frequency Distributions

Leadership Initiatives factor (F.LI) has item LI07 with high mean at 4.13, whilst items LI04 and LI02 had lowest mean of 3.87. LI04 sought to establish whether there is selective promotion of role models in the banking sector. LI02 checked whether social contrast between leadership and employees existed. LI07 wanted to ascertain if the leadership paid special attention to the technology and its usage, for learning and knowledge transfer, as shown in Table 1.

Table 1. Frequency Distribution: Leadership Initiatives

Frequency Distributions: LI (*N* = 100)							
	Mean	S.D.	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
LI07	4.13	0.64	0%	0%	15%	58%	27%
LI03	4.07	0.69	0%	2%	15%	58%	25%
LI01	3.96	0.69	0%	0%	25%	53%	22%
LI05	3.95	0.73	0%	2%	24%	53%	22%
LI06	3.93	0.77	0%	5%	16%	58%	20%
LI04	3.87	0.64	0%	0%	27%	58%	15%
LI02	3.87	0.79	0%	4%	27%	47%	22%

Table 2 shows that, within the items that related to the innovation competitiveness factor (F.IC), the item with the highest mean, at 4.67 (IC03). On the other hand, the lowest mean score was in relation to the item that relates to the level of innovations in the banking sector is of high quality (IC05), at 3.69.

IC04: also relates to innovation competitiveness, testing whether the employees do utilize their skills and knowledge to embrace innovation in their organizations. This item acquired a mean of 4.20, which is very high. IC02: with a mean of 4.09, also high, the respondents were of the view that their management team possesses skills that are aligned to global innovation standards. IC01: In general, the leadership was considered to be the innovation champions, as this item acquired 3.95, also very high. IC06: at a mean of 3.93, which is also high, the culture in the organization promoted new experiments and innovative practices. IC07: at a mean of 3.9, the support structures in the organization were said to be responding promptly to support innovative initiatives.

Table 2. Frequency Distribution: Innovation Competitiveness item

Frequency Distributions: IC (*N* = 100)							
	Mean	S.D.	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
IC03	4.67	0.47	0%	0%	0%	33%	67%
IC04	4.20	0.59	0%	0%	9%	62%	29%
IC02	4.09	0.78	0%	2%	20%	45%	33%
IC01	3.95	0.91	0%	7%	22%	40%	31%
IC06	3.93	0.74	0%	4%	20%	56%	20%
IC07	3.75	0.82	0%	5%	33%	44%	18%
IC05	3.69	0.81	0%	5%	36%	42%	16%

5.2. Cronbach's Alpha

Cronbach's alphas were used to provide a measure of the internal consistency.

F.IC: Innovation competitiveness indicated strong reliability at 0.84.

F.LI: Leadership initiatives, at 0.90, indicated very strong reliability. The sense of direction and inculcation of the knowledge management practices that lead innovative culture strongly lies with the leadership initiatives in the banking sector.

Table 3. Cronbach's alphas coefficients

Cronbach's alpha (*N* = 100)	
F.IC	0.84
F.LI	0.90

5.3. Pearson Product Moment Correlations

Innovative competitiveness (F.IC), factors were found to be strongly related to leadership initiatives (F.LI), at .795 and therefore practically significant.

Table 4. Pearson Product Moment Correlations

Pearson Product Moment Correlations (*N* = 100)		
	F.IC	F.LI
F.IC	-	0.795
F.LI	0.795	-

5.4. One-Sample t-Test

Table 5. One-sample t-Test

One-sample t-Test (*N* = 100)				
Variable	Mean	S.D.	t	p
F.IC	4.04	0.54	8.84	<.0005
F.LI	3.97	0.56	7.55	<.0005

F.IC: Innovation competitiveness had a mean of 4.04, SD = 0.54, t = 8.84, p <.0005, thus highly significant.

F.LI: Leadership initiatives had a mean score of 3.97, SD = 0.56, t = 7.55, p <.0005, thus highly significant.

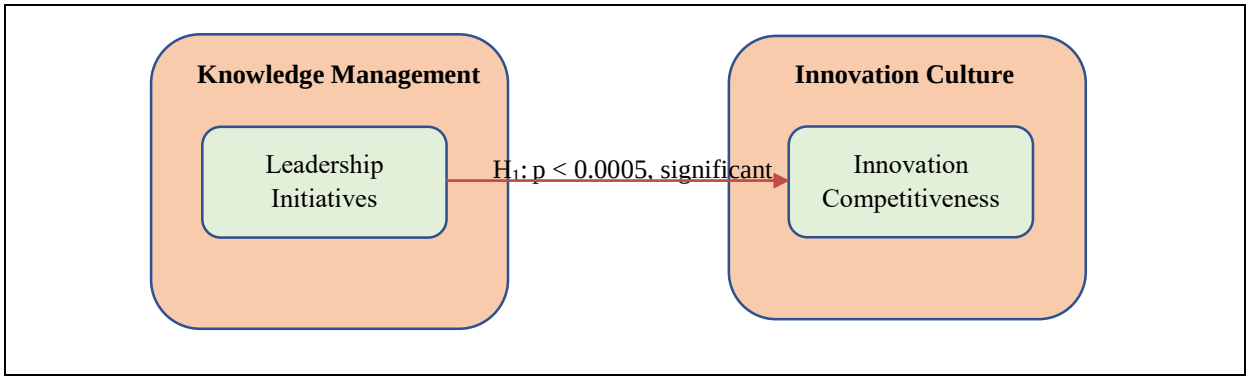

Figure 1. Summary of statistically significant relationships

6. DISCUSSION

From the literature review, it has been shown that knowledge management provides a knowledge-driven culture within which innovations can be incubated. This study identified key attributes relating to knowledge management that the banking sector can leverage on, in order to inculcate the innovation culture, thereby allowing banks to acquire competitive advantage. Since there is scant research to show that the banking sector across South Africa is using knowledge management as a strategic tool to drive an innovation culture, the study provides an insight into initiatives necessary influence knowledge-based culture.

The development and introduction of an innovation-based culture in an organization is critical in the current competitive business environment, where the ever-changing customer

needs have dictated the complex nature of innovation and as such, knowledge management systems have become one of the fastest growing areas of corporate sector.

It has been established that knowledge is the means, which is necessary to possess in order to improve, develop and maintain business processes, enabling fast and appropriate responses to ever-changing environment conditions, therefore leadership is an important critical success factor of knowledge management and is also helpful in successful knowledge management implementation. As the knowledge management is a complex activity so it needs management leadership and support to achieve the highest level of organizational performance. Therefore, the existence of leadership initiatives encourages the use of knowledge management practices. Hence the main findings of the study were that there exists a significant relationship between leadership initiatives and innovation competitiveness.

7. CONCLUSION

The aggressive nature of the banking sector is constantly evolving due to technological innovations and knowledge-driven initiatives of the global business environment. The capability of organizations to remain relevant and competitive require different kind of strategies where knowledge management is the driving force behind such strategies, therefore the systematic methodological investigation performed in this study offered an overview of the initiatives required in order to implement knowledge-driven culture to cultivate an innovation in the banking sector.

From the business point of view, organizations in the banking sector need to use innovative technology to enhance their competitiveness. Such innovative technology requires knowledge-based culture in which there is a diversity of skills where employees could acquire new skills and transforming existing knowledge into new knowledge that is essential for innovation initiatives.

From an economic perspective, this study posits that the long-term survival of the organizations in the South African banking sector require innovative knowledge-oriented leadership because leadership is an important critical success factor of knowledge management. It could therefore be concluded that leadership initiatives give rise to innovation competitiveness.

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CONSTRUCTION PRODUCTIVITY, LEAN PROCESSES AND SUSTAINBILITY

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Abstract: Construction projects timelines, tasks and deliverables are complex milestones that must be met, to deliver the project on time, and under the budget. Performance management is a tool for managers to track projects, and get updates in real time on status, and areas needed for improvements, to keep the project ongoing, and on-track. In today's perspective, society is increasingly demanding that all industry needs to address global environmental impacts, and sustainability goals. Construction industry is not going hand in hand with addressing sustainability challenges on every project, largely because these sustainability goals are seen as cost additive without added value by some stakeholders, looking to meet code requirements only. One of the ways to incorporate new technology and sustainability at the same time is introducing LEAN process in construction. It is integrated and collaborative human centres approach meaning is flexible enough to adapt as technology change and sortal challenges. The new holistic, cohesive, and connected approach in building design, material selection, construction and sustainability, is needed to address these challenges in addition to the project requirements. Productivity is often a challenge. The goal of this research is to develop an awareness and provide bases for developing tools to value and measure correlation and coordination between sustainable aspects, material selection and code compliance, shown as interrelated and dependent process.

Keywords: LEAN, Sustainability, Industry 4.0, LEED, Maslow's Hierarchy

1. INTRODUCTION

The world and the construction industry in it, is further advancing and developing as a complex network with advanced analytics, decision making capabilities with intelligent digital technologies, global communication, and collaboration, becoming increasingly interconnected. The fourth industrial revolution (4IR), commonly called Industry 4.0 is already being introduced, as a wide range of new technologies connecting humans and machines together in an integrated digital/physical ecosystem (Goosen, 2022). These technology innovations include:

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- Advanced high speed data interconnectivity including The Internet of Things (IoT), the Cloud, Processing Big Data and Analytics.
- Technological advancements with implementation of Radio Frequency Identification (RFID), Autonomous Robotics, Drones, Security systems, Smart Manufacturing (SM), Machine Modeling, Product Lifecycle Management (PLM) and Additive Manufacturing (AM).
- Advanced management tools such as: Artificial Intelligence (AI), Virtual Reality (VR), and Human-Computer-Interaction (HCI).

Interconnected society is demanding global approach versus centralized solution, which brings an awareness where an increasing demand to cut waste, cut pollution and reduce the overall adverse environmental footprint throughout all aspects of society is becoming more eminent.

The construction industry did not follow the pace of other industries to incorporate Industry 4.0 advancements, or to completely address societies' concern for environmental challenges, construction impacts and increased productivity. In post hurricane impact areas this can be seen more prevalent. Although there was a brief improvement in year-to-year productivity for a short period after reindexing in 2012, the trend has re-established itself in recent years. Another setback during the pandemic 2019-2023 that brought the global economy in near halt, affected broad aspects of the industry: the construction cost, the increase in the material cost, the material supply, the transportation issues, the loss of qualified labor and the industry losing experienced people that retired early under the uncertainty of the pandemic or changed profession ("Great Resignation"), increased safety protocols, scheduling subcontractors not to create cluster on the job site 2 ft distance, all mentioned resulted in loss of productivity, delays and not meeting the deadlines.

Traditional construction practices result in 90% of construction projects having cost overruns (Aljohani, 2017). Construction is labor intensive process, with project specifics, milestones, target dates to meet, contract requirements, risks, and projects characteristics. Increasing productivity is a challenge while incorporating productivity systems makes it an even more challenging task. By embracing the overall LEAN concept and incorporating specific technological advancements, is possible to realize the gains in productivity and connection of Industry 4.0 world within the construction industry, while reconsidering, developing, (or redeveloping), researching, and embracing for advancements to make consistent productivity gains. By taking this approach we can fulfill societal needs to increase productivity while building with environmental consideration in mind.

2. LEAN AND CONSTRUCTION MANAGEMENT

LEAN construction is a management and design process which seeks to manage material, labor, and time by focusing on value of a project as interconnected, cohesive and collaborative processes. Five LEAN principles as described by Womack and Jones (1996), set the foundation for LEAN application in construction: value, value stream, flow, pull and perfection (Forbes, 2020).

Manriquez describes these six LEAN principles applied to construction into respecting people, delivering value, creating flow, removing waste, continually improving, and optimizing the whole (Manriquez, 2020).

Peter Drucker (1974) connects the dots between being able to measure and the improvement, noting "If you can't measure it, you can't improve it" (Drucker, 1974). Measuring and reporting productivity in construction is often a challenge. There is rarely a consensus on the methodology or the results due to the different stakeholder's objectives.

Economic considerations and conditions, raw materials, and transportation cost, are some factors that influence the costs. Elements that influence productivity:

- *Cost* – completing under or on budget.
- *Schedule* – completing on time, no delays and reaching the milestones with planning for material deliveries, tools and qualified labor needed for the project.
- *Safety* – high safety standards, developing safety programs, continuous training and supervision, construction conducted and completed with zero injuries.
- *Quality* – conformance with specifications carefully prepared for that specific project, followed by QA (Quality Assurance) and QC (Quality Control) documentation and processes.

In a market driven economy, prices are influenced by their availability and demand. For example, when there is a surplus of supply the price is lower, however, when the supply is diminished its price is much higher. Evaluating costs, built up from a cost-price chain where economic factors influence price.

Cohesive collaboration is the key to LEAN, to keep people focused and to implement collaborative and cohesive processes. This addresses the previously noted barriers to incorporate Industry 4.0 gains by addressing human-human and human-machine interactions. A collaborative culture that values the human side of the equation and nurtures cohesive and collaborative approach sets the key to a successful LEAN implementation.

The LEAN mindset means a focus on value. The value of a project as a whole system, not of the individual pieces, is achieved through a people centric approach, emphasizing collaboration with the right productive atmosphere focused on value and continuous improvement while respecting human factors.

Initial LEAN concepts can be found at Henry Ford (Ford, 2003), that implemented management principles in the manufacturing processes while implementing standardization and eliminating bottle necks. He was widely regarded as being the precursors to LEAN thinking, principles that centered around taking care of people. Ford believed that managers should walk around the floor to better understand the work and the workers, workers should be afforded education and means to improve themselves, and the company should service their communities and society at large. In the "Toyota Way", which is considered to be the originator of LEAN processes, there is an evolution which increased and put an accent on the productivity. Toyota's ideas and concepts of how to identify and how to eliminate waste are well documented. Invented pull planning, Just in Time (JIT), the concept that anything that doesn't add value is wasteful, even identified and categorized "the seven wastes" (Forbes, 2020). Toyota had improved the process structure, continuous flow improvement and gave a meaning from theoretical base to practical implementation (Liker, 2004).

In construction terms, LEAN can be incorporated as a set of principles that allows a company to remain focused on the items that add value to the final product, continually evolves, sets for collaborative environment between different stakeholders from the very first beginning of the project constantly improves and timely eliminates the errors during the processes while incorporating the advancements of Industry 4.0.

Construction industry can benefit of 4IR with process integration and automation along the entire value chain, increasing productivity, efficiency, collaboration, and final product quality, while improving key parameters, safety, and sustainability (Oesterreich & Teuteberg, 2016). Should the Owner's preference be to seek LEED certification, communication between parties based on LEAN principles while incorporating LEED credits and requirements can lead to a successful project.

Managing a construction process with people's focus in mind will allow members of the construction industry to capitalize on the advantages that LEAN has to offer. Toyota

accomplished this by allowing people to be valued throughout the process and Just-In-Time process.

The construction industry is fast paced with much needed constat communication between different stakeholders in order to meet the project timeline. Quality of communication is very much related to the continuous improvement processes and value of the human factor on all levels from the field to the administrative input. Keeping people focused, respected and with the ability to grow in a collaborative environment are key elements for good project management, which at times is a challenging task.

To make sure that people are valued in the construction industry it is vital to understand the factors that affect labor productivity. The most significant labor productivity influencing factors: poor labor supervision, delays in payments, poor work environment, lowly skilled labor, and bad weather conditions (Gunduz, 2020).

Other important factors, crucial in productivity aspects, and for project delivery are closely related to a safe working environment and zero accidents on the job site. Once an accident (an incident) happens, workers' morale is affected the most and consequently productivity. "This could of be me" factor is not a condition that can be measured in insurance terms and in direct financial losses following the accident, but indirectly or secondary can damage the project greatly affecting workers' confidence, workers' focus and productivity. LEAN construction practices can address many of these issues and allow for a more productive work force. LEAN production is value centered, human focused, and perfection striving. Productivity is primarily measured by cost. Satisfactory productivity depends on many factors: quality, timeliness, safety, completion on budget but also keeping workers motivation in a collaborative environment.

In the LEAN construction project participants can witness how these attributes can positively affect human productivity. Collaborative communication is the key to labor management in uncertain, complex, and fast track projects. By adopting systems support and teamwork, the workforce has a stake in the accomplishment of the set goals. By moving toward a more human centered approach to supervision while satisfying the basic needs of the workers to be recognized, to be part of the project or process, to belong, to be respected and valued for their unique contributions while increasing their self-esteem and nurture motivation. This provides a basis to encourage project participants to move towards meeting their full potential or self-actualization.

According to Maslow's hierarchy of needs and motivational theory, five-tire (levels) a model of human needs, often expressed in a form of hierarchy starting at the bottom with basic physiological needs, to the top self-actualization (achieving full potential including creative activities), needs felt by everyone to some degree or another and looking for these needs to be met. By creating a strong team atmosphere where all members are valued in a work setting project leader can meet their personal needs while improving productivity. Maslow's hierarchy pyramid of need to motivate people is illustrated on Figure 1 (Mcleod, 2007).

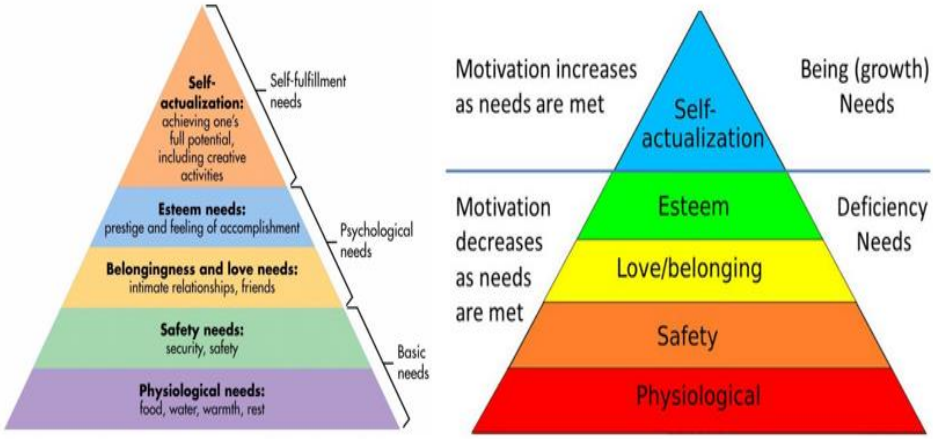

Figure 1. Maslow's hierarchy illustrated (Mcleod, 2007)

Compensation, and the value of the timely payment can also be understood as a basic physiological need. With delay of payment, workers morale decreases, and productivity suffers. Constant improvement, training, and education is a core value of LEAN. This also capitalizes on the *Esteem* and *Self-actualization* aspects of Maslow's Hierarchy. Poor work environment and bad weather or working conditions that are not suitable to the weather situation are problems that lie on the bottom 2 levels of Maslow's Hierarchy.

Another aspect of LEAN construction, off-site manufacturing (OSM), can be a solution depending on the project requirements and Owners' objectives. OSM is becoming more widely used as BIM (Building Information Modeling) and preciseness of building and manufacturing allow for more complete assemblies to be incorporated into build projects (Sabet, 2019). In today construction practices BIM is applied not only at the pre-design and design phase, used in construction for determining structural and other conflicts for timely correction prior construction commences, also depending on BIM dimension (3D; 4D; 5D; 6D; and 7D) 7D recognized dimensions, for modeling (3D), sequencing and timelines (4D) scheduling, cost management and construction cost estimating (5D), sustainability tracing – environmental, social and economic (6D), facility management and lifecycle (7D) in all phases of the facility lifecycle. By building, when project permits off-site manufacturing in environmentally controlled facilities, weather unpredictability or variability can be mitigated, and safety increased if addressed accordingly.

No significant influences from BIM (Building Information Modeling) and OSM (Off-Site Manufacturing) on overall project performance when these techniques were applied individually, but a significant influence from BIM on OSM when the capabilities of the two techniques were interactive, which resulted in a significant influence from OSM–BIM interactions on overall project performance. (Sabet, 2020)

LEAN manufacturing concepts are a natural fit to overcome the 5 most important labor impacts to construction productivity. The team concept, continual education and striving for perfection allow laborers to meet several vital items in Maslow's hierarchy of needs. These together can significantly improve productivity on construction sites, which imparts greater value to the project.

Using LEAN concepts in construction has been proven to work. A case study of Sutter Health's Integrated Process Delivery (IPD) approach to lean construction is often cited. Sutter Health is a not-for-profit community-focused service-oriented healthcare network with over 30 facilities. The California legislature passed laws which required the replacement of health care

facilities throughout the state. In response to this legislature Sutter Health developed a robust building plan which was estimated to need to spend over $5.5B. Although there were some lessons learned and changes made from the first couple of projects, all projects after 2006, except 1 out of 23, have been completed on time or earlier and under budget (Forbes, 2020). This is an impressive feat in an industry known for its extravagant cost overruns and time delays.

3. LEED AND SUSTAINABILITY

Triple bottom line concept in LEED with three pillars of sustainability 3-Ps (People, Planet, Profit) or 3-Es (Environmental, Economic, Equity) need to be in balance between each of the three components, see Figure 2.

"Choices that increase the triple bottom line of an organization can lead to an increase in a market share, for example, a company that lays off a large percentage of workers so that the shareholders can retain a profit in difficult times will not win the favor of consumers, possibly decreasing its market share" (McCombs, 2015).

Per McCombs (2015), in direct comparisons between building types, green buildings cost approximately 2% more than non-green buildings. The cost of the material is another aspect of the construction, depending on the specific manufacturing instructions related to the handling and the installation and the maintenance, may contribute to productivity in either way.

Closed and open systems are differently linked to sustainability. Open systems, cradle-to-grave materials are not sustainable, since they are extracted, manufactured, purchased, utilized, and disposed with a beginning and an end of the lifecycle process.

Closed loop systems, cradle-to-cradle systems have a process of re-use that begins again at the end of its useful life. This process contributes to the eliminating of waste, by reusing.

Integrated process is the base of sustainability and the green building design and construction, by implementation of multidisciplinary teams and integrated strategies and same is part of LEED (Leadership in Energy and Environmental Design).

Per Taiichi Ohno, creator of the Toyota Production System (TPS), all industrial thinking must begin by differentiating value for the customer from *muda* (the Japanese terminology for waste, Ohno's seven-wastes). He is also known for the "Ten Precepts" to think and act to win.

The process can be described with the three critical activities in any business: product definition (design definition from concept to detailed, from engineering to production), information management (from take-off to planning, scheduling and delivery) and physical transformation (from material to the delivery of finished product) via identifying and defining the value stream (Womack & Jones, 1996).

A study in 2020 showed that labor cost is the largest operating cost in office buildings 95% and higher for the employer in the office building, where green building demand higher rents, and that the improved environmental aspects of green buildings increased the productivity of its workers (Zhivov, 2020).

Figure 2. The three pillars of sustainability

4. CONCLUSION

Technological advancements in all fields continue to grow at an exponential rate. The value on sustainability and lessening our environmental impacts in all endeavors is gaining more momentum. Productivity has always been a challenge, but LEAN adaptive process can provide structure to address and improve workers' productivity in the long run for various projects. LEED is the most recognized green building certification program, followed by Green Globes, and BREAM. Incorporating these technological advancements, while meeting societal environmental concerns, into the construction industry has been a challenging task. It is estimated that 9 in 10 traditionally managed construction projects experience cost overruns (Aljohani, 2017). Every project is unique, different than the previous one. Construction is a unique, and labor-intensive endeavor. Complying with environmental building standards has been viewed as cost prohibitive. There are many different stakeholders involved in a project (designers, architects, owners, contractors, sub-contractors, suppliers, inspectors, compliance officers) all with their own, often competing, interests.

Addressing productivity at the front end of the construction project before commencement of the project and delivering methods for resolution of possible fluctuation in productivity based on established criteria and areas of uncertainty is the only way to tackle the productivity ahead of the time. Wide fluctuations in the completion of tasks need to be analyzed realistically, the risk of scheduling labor and materials for tasks that are not in a full state of readiness and planning for solutions for delayed projects. Keeping available crews for delayed assignments can be a very costly adventure and can fail the project. Due to the increased cost of the labor, crews need to be continuously engaged on tasks that can produce income and not to be kept on idle mode if project is delayed.

To effectively incorporate Industry 4.0 advances and sustainability initiatives an overall management structure needs to be adopted which can take these individual parties and create a unified team working together to make a productive and profitable construction project. LEAN appears to be the best framework to accomplish this task and it has multiple success stories. There are overlaps between the LEAN construction goals and concepts, and LEED building certification goals and concepts.

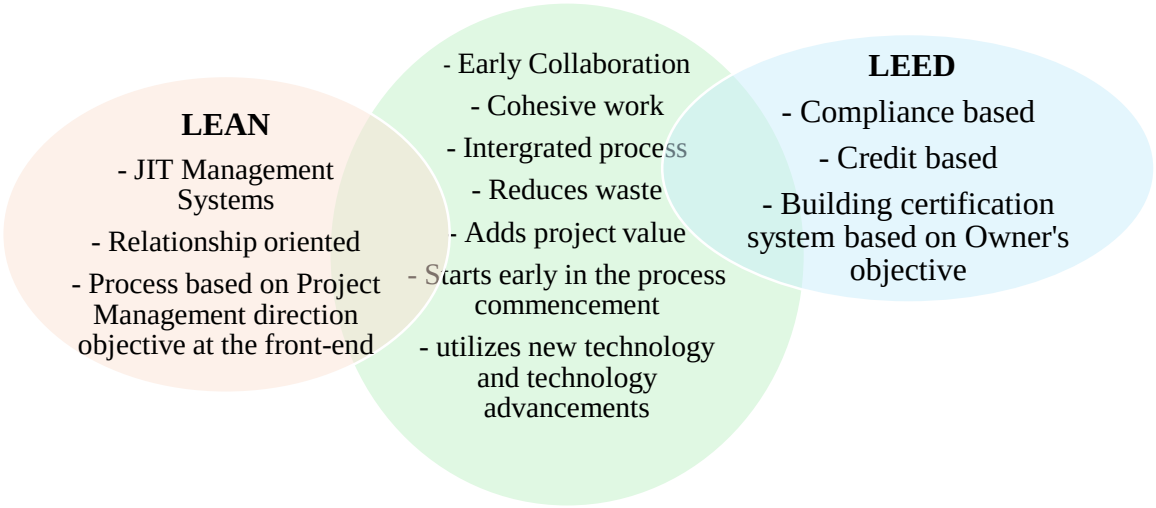

Figure 2. Intersection, areas where LEAN and LEED similarities can contribute to project overall project success

While LEAN is a relationship-oriented management system which uses integrated processes available by using advanced technologies to reduce waste and add value to a project, LEED certifies these advancements as they relate to sustainability and environmental impacts. Because they are so closely aligned it makes good sense that if projects are considering LEED certification, they should consider LEAN for construction management.

Principles and goals of Industry 4.0 technologies will contribute to a more sustainable society, building competitiveness of firms and especially when capital investment decisions are to be made (Bai & Sarkis, 2020).

IPD (Integrated Project Delivery) method and BIM ultimately will improve the design coordination, and construction management process and contribute to collaborative and integrated action, along with creativity and reliability, implementing LEAN construction will lead to a successful project delivery.

Safety will remain to be a major topic. Human supervision is needed, although the new technology utilized in the field can contribute to the overall construction process. The possible use of AI (Artificial Intelligence), AR (Augmented Reality), drones, utilization of the new technologies in the working space, ability to send updates in real time, 3D printing, possibility to make a part or material on site or offsite while complying with the specifications to finish the project and use of sustainable materials, are promising solutions for sustainable future.

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TOWARDS A POLICY OF CONTINUOUS, SUSTAINABLE IMPROVEMENT IN HOSPITAL WASTE MANAGEMENT: A CASE STUDY

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Abstract: Public and private healthcare establishments generate various forms of potentially harmful waste, the rational disposal of which is one of the essential conditions for compliance with hygiene rules, not only within the establishments themselves, but also in the general environment. The specific nature of solid waste produced by healthcare establishments means that it has to be disposed of in a way that is, in many cases, far from satisfactory, given the objectives set out above. As a result, because of their potential for hazardousness and contamination, healthcare waste (HCW) requires special attention, and even effective, sustainable management. Accordingly, as part of our study, we conducted a survey of 18 clinics at Constantine University Hospital to identify the types and daily quantities of waste generated. Within this panorama, the quantity of waste generated is a major strategic indicator, dictating various aspects of sustainable management. Precise identification of the quantities of waste generated by each clinic now provides a sound basis for the formulation of policy and strategy for the sustainable management of healthcare waste, and consequently for better supply chain management. The results of this study show that infectious risk waste is the most dominant waste in 11 clinics.

Keywords: Environment, hospital waste management, reverse logistics, supply chain, public health.

1. INTRODUCTION

Public and private healthcare establishments generate various forms of waste that are potentially hazardous and harmful to public health. Their rational disposal is one of the essential conditions for compliance with hygiene rules (Windfeld & Brooks, 2015; Noela & Veronica,

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2024), not only within the establishments themselves, but also in the general environment. Among these pollutants, solid waste is undoubtedly one of the most complex to resolve (Abdel-Shafy & Mansour, 2018; Rodić & Wilson, 2017; Ludwig et al., 2012). The specific nature of solid waste produced by healthcare establishments means that it is subject to special management and disposal requirements, which in many cases are far from satisfactory, given the objectives set out above. Consequently, in order to achieve the objective of a sustainable healthcare supply chain, and given the constant evolution of healthcare systems and the growing importance attached to public health and environmental protection, it is necessary to improve and control hospital waste management. As a result, hospital waste management represents one of the main challenges for healthcare establishments according to the World Health Organization (WHO) (WHO, 2005; Barbosa & Mol, 2018; Odonkor & Mahami, 2020; Singh et al., 2022). Consequently, the continuous, sustainable and permanent improvement of waste management improves safety, employee health, the protection of society and the preservation of the environment, hence the need to use reverse logistics. Reverse logistics takes care of the reverse journey in the supply chain. It comprises several stages, including the collection, sorting, control, storage and processing of the products used (Yu et al., 2020; Balci et al., 2022; Govindan et al., 2022). As a result, the processes and technologies available for waste management must be widely deployed to minimize their harmfulness, hazard and contamination potential. As a result, the hazardous waste generated in hospitals, because of its potential for danger, threat and contamination, requires special attention, if not effective and sustainable management. According to UN classification, medical waste is considered the most hazardous waste after radioactive waste (Basel Convention, 2004; Padmanabhan & Barik, 2019; Janik-Karpinska et al., 2023). The efficient and sustainable management of this waste is crucial for the life and health of patients and medical staff, as well as for the environment and public health. In this context, the quantity of healthcare waste produced is positioned as a key strategic indicator, influencing various aspects of sustainable management (Maniatis, 2016; Mousa & Othman, 2020; Abdelkareem et al., 2022). The aim of this work is to correct some of these shortcomings, based on an in-depth analysis of existing hospital waste management. Thus, we have opted for a descriptive method, based on the principle stated by the international standards organization on World Standards Day, that the quantity of waste is of paramount importance to its management "Less waste, better results - Standards increase efficiency" (ISO 2012).

2. RISKS ASSOCIATED WITH MEDICAL WASTE

Healthcare activities help to protect health, heal patients and save lives. However, they also generate waste, approximately 20% of which represents an infectious, toxic, traumatic or radioactive risk. This presents risks of threat and contamination for both society and the environment (Akni & Chaib, 2020; Kharzi et al., 2022). It is therefore essential to manage them safely, and even to choose the most appropriate management method for each type of waste. Today, controlling these risks is a major asset for patients, public health and the environment. Two categories of risk can be distinguished:

- For public health:

Anyone who comes into contact with hazardous medical waste is potentially exposed to the various risks it poses (Babanyara et al., 2013; Perkins et al., 2014; Ansari et al., 2019; Padmanabhan & Barik, 2019). Such waste is potentially contaminated with pathogenic

biological agents. Healthcare waste is a reservoir of potentially dangerous microorganisms, capable of infecting patients, staff and the general public. There are multiple routes of exposure: by wound (cut, puncture), skin or mucous membrane contact, inhalation or ingestion.

Algerian law confirms that, when handling health-care waste, the personnel responsible for pre-collection, collection, transport and treatment must be equipped with personal protective equipment resistant to punctures and cuts. They must be informed of the risks involved in handling waste, and trained in good waste handling practices (OFFICIAL JOURNAL OF THE ALGERIAN REPUBLIC, 2003).

- For the environment:

Hospital waste causes environmental degradation (Mukhtar et al., 2018; Ansari et al., 2019; Rana et al., 2023), with inadequate management of waste, particularly DAS, resulting in : 1) Contamination of water sources when waste is processed, or when it is disposed of in a pit that is not insulated or close to a water source; 2) Air pollution due to the emission of highly toxic gases (dioxins, furans, etc.) released during poorly controlled or open-air incineration of waste (ICRC, 2011). 3) Toxic emissions (heavy metals, dioxins, furans, fly ash) that present a health risk and do not comply with environmental health regulations in the absence of pollution control devices (WHO, 2005). 4) Unauthorized and abusive incineration and/or dumping of healthcare waste pollutes the air with hazardous gases and contaminates soil and water with heavy metals and other toxic chemicals, which can enter the food chain, causing respiratory tract diseases and cancer (DELIVER Project, 2014).

By way of illustration, dioxins and related substances cause cancers of the liver, digestive tract and blood. They are also considered to be responsible for dermatological (chlorinated acne), cardiac-vascular, hepatic and endocrine disorders, as well as disorders of sensual organ development and reproduction. This last property may constitute their main toxicity, since it is capable of deregulating the function of sex hormones at doses corresponding to current population exposure (Regional Centre for Environmental Health Activities, 2004).

3. DATA AND METHODOLOGY

To identify the types of waste generated in the hospital and measure their daily quantity, we surveyed 18 different clinics, such as the central pharmacy, three laboratories (bacteriology, toxicology and chemistry), the medical and surgical clinics (cardiology, Human Anatomy, Chemotherapy, physiology, orthopedic traumatology clinic, central pharmacy, neurosurgery, endocrinology, orthopedic surgery, pediatric emergency, burn center, medical resuscitation, dental emergency, maxillofacial and ENT). The advantage of quantifying daily waste production in each clinic lies in knowing the weight and volume of waste produced on a daily basis, so that it can be managed rationally (Brussels High Council of Hygiene, 2005). This will enable us to anticipate the need for waste collection, conditioning and treatment equipment (rollers, bags, containers, garbage cans, treatment equipment, etc.).

Then, to better assess the quantity of waste produced and identify the necessary resources (bags, tools and equipment, etc.) for sustainable management, we used a Pareto chart to determine the predominant types of waste in each clinic, or even to map the waste in each facility. This enables us to draw up an action plan based on the reality on the ground.

Consequently, our work is based on the analysis and comparison of different quantities and qualities of solid waste generated by the various services and the adapted management methods, where we have highlighted three categories of services in relation to the predominant types of hazardous waste they produce.

Finally, we recommended a few practices to be followed by the hospital for effective, sustainable and continuous waste management.

4. RESULTS AND DISCUSSION

The quantification of healthcare waste is a strategic indicator for a sustainable management policy. In this section, we collected data and carried out surveys in the various hospital clinics in order to assess the distribution of the various types of waste generated in this establishment, as illustrated in Figure 1.

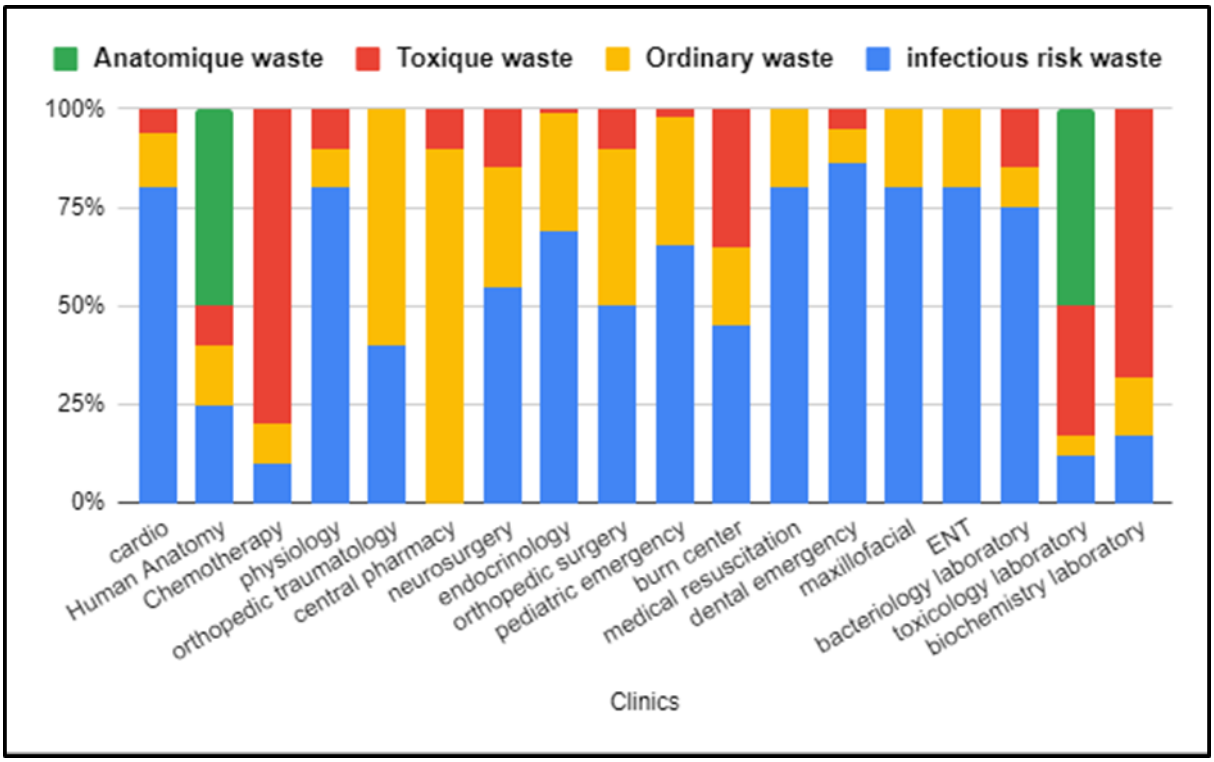

Figure 1. Distribution of medical waste generated by clinic

We note that the central pharmacy alone generates 90% of ordinary, generally non-hazardous waste. However, the chemotherapy clinic generates 80% of chemical waste, followed by the biochemistry lab with 65%, then the toxicology lab and the burns center with approximately 35%. This waste contains chemicals, including CMRs. This calls for a high level of precaution, which is marked by the rule that, as a matter of principle, a chemical product is dangerous. Concerning infectious risk waste, the emergency stomatology clinic produces 86%, 30% of which is sharps waste, the cardiology, physiology, medical intensive care, maxillofacial and ENT clinics produce 80%, of which 60% and 45% is sharps waste in the cardiology and maxillofacial clinics. The bacteriology laboratory, endocrinology, pediatrics and neurosurgery clinics generate 75%, 69%, 60% and 55% respectively. For anatomical waste, two clinics generate 50%: human anatomy and the toxicology laboratory.

After analyzing the results, we found that each clinic has its own specific characteristics in terms of waste generation. We have thus identified three categories of service, according to the types of hazardous waste (infectious, toxic and anatomical) that are present in the majority (over 50%), as illustrated in the following figure, Figure 2. We note that, for all services, infectious waste is the most predominant. We note that, for the totality of the clinics, infectious risk waste is the most dominant, and it is the case in 11 clinics.

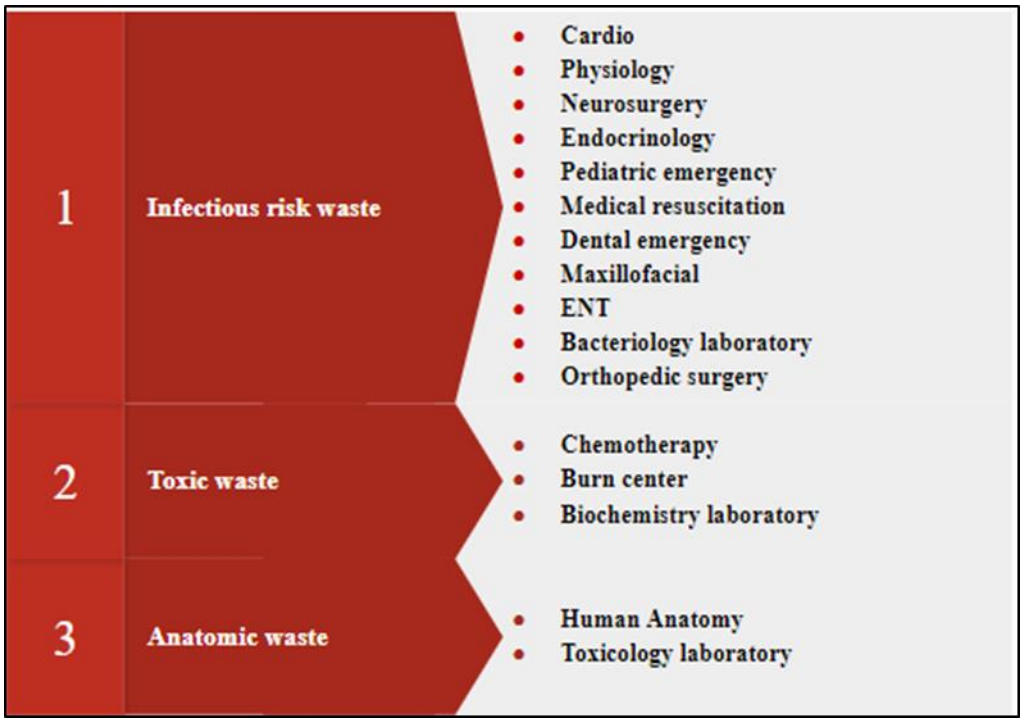

Figure 2. Categories of services according to waste production

Based on the results obtained in the field, an action plan has been drawn up with a number of reverse logistics practices to better manage this healthcare waste management operation within the facility.

Finally, to avoid health risks and ensure proper management of hospital waste, we recommend the following practices:

- Training of hospital staff: Provide adequate training for hospital staff on best waste management practices, including appropriate segregation of waste, use of specific containers, and safe handling of hazardous substances. Information on cleaning techniques and protocols should be clearly and prominently displayed.
- Provision of protective equipment: Workers must be provided with suitable protective equipment, such as boots, apron, mask and gloves.
- Providing the vaccinations: enable all personnel in contact with medical waste, including cleaning teams and technicians, to have access to appropriate vaccinations.
- Setting up selective collection systems: Create collection systems that allow different types of medical waste to be sorted at the point of generation. This reduces the quantity of infectious risk waste and facilitates the process of recycling and appropriate treatment.
- Compliance with packaging rules: supply good-quality bags and containers with the various color codes specified in the regulations, seal bags and containers.
- Setting up dedicated storage areas: Create specific, secure storage areas for different types of medical waste, taking into account safety, health and environmental protection requirements. Use specially designed containers for temporary storage of hospital waste.

- Use of tracking and traceability technologies: Integrate technologies such as barcodes or RFID chips to track and trace medical waste throughout its life cycle, from generation to final disposal. This will help control the amount of waste generated.
- Continuous monitoring and evaluation: Set up a monitoring and evaluation system to track hospital waste management performance, identify areas for improvement and implement corrective measures where necessary.
- Use of appropriate hygiene methods: disposable products can, in fact, increase the volume of hospital medical waste and entail financial costs, so it's advisable to use appropriate hygiene methods for cleaning reusable items such as sheets, non-disposable surgical instruments and dishes.
- Medical consumables recycling: Explore recycling options for certain single-use medical consumables, such as syringes, latex gloves and compresses. Some specialized companies offer collection and recycling programs for these items.

5. CONCLUSION

The treatment of medical waste is first and foremost a management issue, rather than a technical one, and is therefore totally dependent on the commitment of all health-care facility staff. In addition, medical waste management systems accept ethical responsibility. Health-care waste must be managed in a specific and rational way, to avoid any harm to human health or the environment, or the need to carry out a preliminary study of the waste produced or likely to be produced in hospitals, to determine its quantity and type, and to plan the necessary packaging, storage, transport and treatment materials and equipment, as well as the personnel required for this management, taking into account, among other things, the hospital's occupied bedding capacity and the number of its units. However, it should be noted that waste management at the Constantine University Hospital suffers from human, material, financial and organizational constraints. Improved management will inevitably require the removal of these constraints, which in turn will require the involvement of managers at all levels, harmonious and effective inter-sectorial coordination and collaboration, and the preparation of even a simple waste management plan setting out objectives, activities, players and their remits, the necessary resources, as well as monitoring, supervision and control mechanisms.

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Original research

OBSTACLES OF WOMEN MANAGERS IN THEIR CAREERS, THE GLASS CEILING PHENOMENON

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Abstract: With equal level of education and competency, both men and women should theoretically have equal opportunities for employment and career advancement. However, reality is quite different. Existence of an invisible barrier, known as a glass ceiling or glass labyrinth, has been recognized long ago. It is terminology used to describe obstacles women face when advancing to leadership positions and in their managerial careers in general. This barrier is rooted in and reflects socio-economic inequality, workplace dynamics, unresolved patriarchal culture, and legacies from the past.
This research aims to identify the barriers of the glass ceiling and assess their impact on women's positions in the business world, particularly in management, where women are underrepresented despite constituting a significant portion of the workforce.
A prospective study was conducted in November 2023 on a random sample of 120 female managers employed across various sectors in Republic of Srpska, Bosnia and Herzegovina. Data were collected through anonymous questionnaires and analyzed using IBM SPSS 23.0.
Results of the analysis reveal that one of the major obstacles faced by women managers is family obligations and childcare responsibilities. Younger women managers with lower income perceive more career barriers compared to their more experienced female colleagues in higher positions with higher incomes.

Keywords: women managers, career barriers, glass ceiling, business management.

1. INTRODUCTION

The glass ceiling is a concept that refers to the barriers encountered by women who attempt or aspire to reach higher managerial positions within companies, government and

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educational institutions, and healthcare facilities. It is an invisible barrier that prevents women from reaching the highest leadership positions (Ljubičić, 2016). The term encompasses all the obstacles women face in their professional advancement, which are not clearly visible, cannot be overcome, and hinder the promotion of women regardless of their success.

Although women make up half of the workforce in developed countries and achieve better results in education, they hold only about 8% of top managerial positions (Tešanović, 2019). Additionally, women earn approximately one-third less than men on average for the same job and level of responsibility. Despite outperforming men in education-related jobs, they lag far behind when it comes to the highest-paid managerial positions. Psychologists argue that women are less prone to risk-taking than men, and a willingness to take risks helps them advance in their careers, earn higher salaries, and secure higher positions (Wasko et al., 2011). The responsibility for childcare and family falls heavier on women than on men because they assume this obligation. This is precisely one of the major reasons hindering access to better positions and higher incomes. Many employers are reluctant to hire younger women, bluntly asking them whether they plan to have children. Higher-paying positions are less flexible and require more dedicated time. It has also been shown that in marital situations where women earn more than men or hold higher positions, marriages often break down and frequently lead to divorce (Bowling et al., 2015).

The most common obstacles within the glass ceiling include: prejudices – men are promoted faster than women despite having the same qualifications, even in traditionally so-called "female" areas such as education and healthcare; resistance to female leadership – successful women managers are perceived as selfish, aggressive, and assertive unlike male managers; leadership style issues – many female managers struggle to find the balance of the qualities that people appreciate in women (empathy towards others) with qualities considered necessary for successful management (assertiveness and control); family demands – women are still the ones who interrupt their careers to balance family obligations, thereby losing time for the networking engagement necessary for advancement (Bakšić et al., 2022).

In this context, this research aims to uncover the reasons for the glass ceiling that prevents women managers from being in top management.

2. REVIEW OF LITERATURE

Is workplace inequality based on differences in expectations? A study by the Careerbuilder.co.uk portal, conducted on a sample of 3700 employees from European Union countries and the USA, shows that the glass ceiling is present to a greater or lesser extent in almost all countries. The results of this study have shown that men are more inclined to expect higher levels of jobs throughout their careers – 29% of men believe they will reach director-level or higher, compared to 22% of women. A quarter of women (25%) never expect to reach beyond an entry-level role, compared to 9% of men. Almost a third of women (31%) believe they have encountered a glass ceiling within their organization and are less satisfied with job advancement opportunities. Only 34% of women are satisfied with career advancement opportunities at their current employer, compared to 44% of men, while 30% of women do not believe they have the same career advancement opportunities as men with the same skills and qualifications in their organization, compared to 12% of men. Also, they are less satisfied with the training and additional education provided by their employer compared to men (43%:55%).

There are three different opinions on the phenomenon of the glass ceiling (Adamović, 2011). Some explain it by differences in investing in human resources (women and men), as some studies have shown that less investment is made in women, their education, training, and work experience. This results in fewer women with the necessary qualifications and is

symbolically called the "pipeline problem," which leaks as we approach the top (Cohen et al., 2020). Also, family responsibilities and childcare disproportionately burden women, which is another reason why they have slightly less work experience and discontinuity in their careers. Women with children find it harder to find jobs and are more likely to lose them, facing constant family-work conflicts (Fiksenbaum, 2014). Often, after a break due to childbirth, they start again from a lower position than they held before. Women are less likely to be encouraged and involved in key networks to gain opportunities for professional development and training compared to men. This is certainly also related to prejudices about female leaders, and it has been proven that women have fewer opportunities to get mentors and establish informal mentoring relationships in the business environment (Deemer et al., 2014).

Another group of opinions assumes that the glass ceiling exists because men and women are different (Meyerson & Fletcher, 2020). One argument is the differences in management styles and effectiveness. Since the glass ceiling makes it difficult for women to climb to the highest positions, those who succeed are mostly exceptionally competent, which argues in favor of female superiority and leadership advantages (Sharma & Kaur2019). On the other hand, there is an assumed difference in dedication to work and motivation for leadership roles, but it has been proven that women have the same level of dedication to work, and both women and men consider their role at work secondary to their role in the family (Babić et al., 2020). Research has also shown that women are less likely to highlight their leadership qualities to take on leadership positions compared to men (Babic & Hansez 2021). Women face gender biases, and that is why society considers them less acceptable and less desirable for employment if they highlight their qualities (Milinović, 2017).

A third group of explanations for the existence of the glass ceiling believes that prejudice against women leaders and their discrimination are the cause (Ljubičić, 2016). Among other things, stereotypical expectations are that women should take care, and men should take control (Bakker & Demerouti 2007). Stereotypes are widespread and highly resistant to change, making it difficult to change them to the extent that they are inaccurate or prevent individuals from recognizing that there are differences among people. Research on managerial characteristics has shown that stereotypes apply to men, such as reliability, perseverance, independence, rationality, and decisiveness, while stereotypical attributes for women include caring for others, sensitivity, warmth, providing help, and nurturing (Dahl et al., 2009). Gender stereotypes are easily activated and produce judgments based on prejudices, especially when it comes to leadership roles, particularly to the detriment of women (Williams, 2000).

3. RESEARCH METHODOLOGY

The subject of research in this paper is to uncover and explore the reasons for the glass ceiling that prevent women managers from reaching the highest management positions. The aim of the research is to determine their impact on the position of women in the business world, especially in the sphere of management where women are currently least represented, despite the fact that the percentage of the female workforce is significantly higher.

A prospective study was conducted in November 2023 on a random sample of 120 women managers employed in banks, postal services, public administration, healthcare institutions, as well as companies engaged in the production and sale of goods and services in the territory of Republika Srpska, Bosnia and Herzegovina. For the implementation of the research itself, a research instrument used is an anonymous questionnaire. The collected data were analyzed using the IBM SPSS Version 23.0. The results of the research are presented in the text below, drawing conclusions about the impact of invisible barriers that hinder the representation of women managers in top managerial positions.

4. RESULTS OF RESEARCH AND DISCUSSION

Within the scientific field of business management in Bosnia and Herzegovina and the surrounding region, there are very few such researches. Therefore, we believe that this paper will contribute to establishing a common groundwork for future research on invisible barriers affecting women in business from attaining the highest leadership positions. In this part of the paper, we will present the results of the conducted primary research related to the study objectives. What are the most significant factors, and to what extent do they negatively affect the careers of women managers? Therefore, we explored family or marital reasons such as responsibility for childcare, economic, social, cultural, working conditions and work environment, as well as other factors (level of education, marital status, number of children, work experience) that influence the success of women managers' careers.

Table 1. Demographic Variables

	n=120	%
Gender		
Female	120	100.0
Age		
25-35	69	57.50
36-50	48	40.00
+50	3	2.50
Marital Status		
Married	87	72.50
Single	33	27.50
Number of Children		
one child	45	37.50
two children	36	30.00
more than two children	39	32.50
Total Work Experience		
Up to 10 years	18	15.00
11 – 20	21	17.50
21 – 30	51	42.50
Over 31 years	30	25.00
Managerial tenure		
Up to 10 years	78	65.00
11 – 20	27	22.50
21 – 30	12	10.00
Over 31 years	3	2.50
Level of education attained		
High school	3	2.50
College 180 ECTS	21	17.50
College 240 ECTS	87	72.50
Postgraduate studies +300 ECTS	9	7.50
Monthly earnings (1 EUR=1.95583 BAM)		
Up to 1000 BAM	9	7.50
1000-1500 BAM	36	30.00
1500-2000 BAM	12	10.00
Over 2000 BAM	63	52.50

Analysis of demographic data shows that all respondents were female, with the majority (57.5%) falling within the age range of 25-35 years. Out of the respondents, 87 were married (72.5%), with the majority having one child (37.5%), while 32.5% had more than two children. The largest percentage of respondents (42.5%) had a total work experience between 21-30 years, with 65% of them having less than 10 years of managerial experience, indicating lower representation of women in managerial positions. In terms of education, the majority of respondents had completed the first cycle of higher education, while postgraduate studies were

completed by 7.5% of respondents. In terms of monthly earnings, 52.5% reported earnings over 2000 BAM (1023 EUR), followed by 30% of respondents reporting earnings between 1000-1500 BAM (511.29-766.94 EUR). (Table 1).

The respondents are employed women across various sectors including banks and financial institutions, public administration, healthcare institutions, government agencies, and public and private companies involved in the production and sale of goods and services (Table 2). In private companies, competition for positions is typically intense; however, there are often better opportunities for career advancement based on performance and merit. Private companies may also demonstrate greater flexibility in adjusting working conditions to accommodate employee needs, such as offering flexible working hours tailored to family commitments.

As a result, research findings indicate that 39.17% of respondents are employed in private companies involved in the production and sale of goods and services.

Table 2. Employment Sectors of Women Managers

The sector of economic activities	n=120	Rate %
Public administration and Healthcare institutions	32	26.67
Banks	27	22.50
Production and sale of goods and services	47	39.17
Postal services	14	11.66

Based on the Crombach Alpha coefficient depicted in Table 3, it can be inferred that the utilized measurement scale exhibits good reliability ($\alpha < 0.7$), thereby affirming its validity as a tool for gauging the attitudes and opinions of the respondents.

Table 3. Analysis of Reliability of Applied Measurement Scales

	Number of Questions	Value of Cronbach's Alpha Reliability Coefficients
Personal and professional reasons affecting women managers	19	0.746

Although, government services may offer job security, well-defined procedures, and benefits, but they may sometimes provide fewer opportunities for rapid career advancement and workplace innovation, as well as less flexibility in adjusting working hours.

Data from Table 4 underwent one-way analysis of variance (ANOVA) to determine whether there is any statistically significant distinction among the career barriers perceived by women managers across different age groups. The analysis results indicate that there is no significant distinction in the levels of career barriers across various age groups ($p>0.05$).

Table 4. Relationship between Career Barriers and Age

Title of Career Barrier	Age	n	$\bar{X}$	SH_x	VAR. K.	K.T.	K.O.	F	P
Family Obligations - Responsibility for Childcare	25-35	69	3.54	0.48	Inter-group	0.331	0.166	0.606	0.551
	36-50	48	3.40	0.56	Intra-group	10.117	0.273		
	+50	3	3.85	-	Total:	10.448			
	Total:	120	3.49	0.51					
Economic Reasons	25-35	69	3.21	0.55	Inter-group	0.696	0.348	1.239	0.302
	36-50	48	3.44	0.49	Intra-group	10.398	0.281		
	+50	3	2.85	-	Total:	11.094			
	Total:	120	3.30	0.53					
Social Reasons	25-35	69	3.14	0.65	Inter-group	0.098	0.049	0.114	0.892
	36-50	48	3.22	0.65	Intra-group	15.899	0.430		
	+50	3	3.00	-	Total:	15.997			
	Total:	120	3.17	0.64					
Work Environment	25-35	69	3.03	0.61	Inter-group	1.146	0.573	1.648	0.206
	36-50	48	3.36	0.54	Intra-group	12.870	0.348		
	+50	3	2.80	-	Total:	14.016			
	Total:	120	3.16	0.59					
Other Reasons	25-35	69	3.63	0.49	Inter-group	0.279	0.139	0.787	0.463
	36-50	48	3.46	0.28	Intra-group	6.548	0.177		
	+50	3	3.66	-	Total:	6.827			
	Total:	120	3.57	0.41					

The relationship between career barriers faced by women managers and marital status was analyzed using an independent t-test for groups. The analysis results indicate that there is no significant statistical difference between the scales of career barriers and marital status ($p>0.05$, Table 5).

Table 5. Relationship between Career Barriers and Marital Status

Title of Career Barrier	Marital status	n	$\bar{X}$	*S.S.*	F	t	P
Family Obligations – Responsibility for Childcare	Married	87	3.53	0.45	3.124	0.702	0.487
	Single	33	3.40	0.67			
Economic Reasons	Married	87	3.34	0.51	0.044	0.860	0.395
	Single	33	3.18	0.57			
Social Reasons	Married	87	3.05	0.55	2.224	-1.951	0.058
	Single	33	3.48	0.76			
Work Environment	Married	87	3.14	0.57	0.972	-0.257	0.799
	Single	33	3.20	0.69			
Other Reasons	Married	87	3.59	0.44	0.690	0.655	0.517
	Single	33	3.50	0.33			

Table 6. Relationship between Career Barriers and Number of Children

Title of Career Barrier	Number of Children	n	$\bar{X}$	SH_x	VAR.K.	K.T.	K.O.	F	P
Family Obligations - Responsibility for Childcare	one child	45	3.30	0.66	Inter-group	0.925	0.463	1.797	0.180
	two children	36	3.65	0.38	Intra-group	9.523	0.257		
	more than two children	39	3.57	0.36	Total:	10.448			
	Total:	120	3.49	0.51					
Economic Reasons	one child	45	3.35	0.56	Inter-group	0.253	0.126	0.431	0.653
	two children	36	3.17	0.54	Intra-group	10.841	0.293		
	more than two children	39	3.35	0.51	Total:	11.094			
	Total:	120	3.30	0.53					
Social Reasons	one child	45	3.22	0.75	Inter-group	0.380	0.190	0.450	0.641
	two children	36	3.02	0.59	Intra-group	15.618	0.422		
	more than two children	39	3.25	0.56	Total:	15.997			
	Total:	120	3.17	0.64					
Work Environment	one child	45	3.24	0.61	Inter-group	1.191	0.595	1.718	0.193
	two children	36	2.90	0.47	Intra-group	12.825	0.347		
	more than two children	39	3.30	0.65	Total:	14.016			
	Total:	120	3.16	0.59					
Other Reasons	one child	45	3.61	0.39	Inter-group	0.219	0.109	0.613	0.547
	two children	36	3.45	0.51	Intra-group	6.608	0.197		
	more than two children	39	3.62	0.34	Total:	6.827			
	Total:	120	3.57	0.41					

The results of the analysis presented in Table 6 indicate that there is no significant difference between the scales of career barriers and the number of children women managers have ($p>0.05$).

Table 7. Relationship between Career Barriers and Total Work Experience

Title of Career Barrier	Total Work Experience	n	$\bar{X}$	SH_x	VAR.K.	K.T.	K.O.	F	P
Family Obligations - Responsibility for Childcare	Up to 10 years	18	3.61	0.46	Inter-group	0.496	0.165	0.599	0.620
	11 - 20	21	3.26	0.67	Intra-group	9.952	0.276		
	21 – 30	51	3.53	0.42	Total:	10.448			
	Over 31 years	30	3.51	0.59					
	Total:	120	3.49	0.51					
Economic Reasons	Up to 10 years	18	3.14	0.68	Inter-group	1.199	0.400	1.453	0.243
	11 - 20	21	3.00	0.57	Intra-group	9.895	0.275		
	21 – 30	51	3.45	0.50	Total:	11.094			
	Over 31 years	30	3.34	0.41					
	Total:	120	3.30	0.53					
Social Reasons	Up to 10 years	18	2.83	0.72	Inter-group	1.850	0.617	1.569	0.214
	11 - 20	21	2.95	0.59	Intra-group	14.148	0.393		
	21 – 30	51	3.39	0.61	Total:	15.997			
	Over 31 years	30	3.16	0.61					
	Total:	120	3.17	0.64					
Work Environment	Up to 10 years	18	3.20	0.74	Inter-group	3.471	1.157	3.950	0.016
	11 - 20	21	3.00	0.56	Intra-group	10.545	0.293		
	21 – 30	51	3.45	0.47	Total:	14.016			
	Over 31 years	30	2.74	0.49					
	Total:	120	3.16	0.59					
Other Reasons	Up to 10 years	18	3.66	0.47	Inter-group	0.162	0.054	0.292	0.831
	11 - 20	21	3.45	0.52	Intra-group	6.665	0.185		
	21 – 30	51	3.56	0.40	Total:	6.827			
	Over 31 years	30	3.60	0.37					
	Total:	120	3.57	0.41					

One-way analysis of variance (ANOVA) is employed to determine whether there are any statistically significant differences between the career barriers encountered by women managers and their overall work experience. The results presented in Table 7 indicate a statistically significant difference between the career barriers arising from the work environment and the total work experience, at least within one group.

Table 8. Relationship between Career Barriers and Managerial Tenure

Title of Career Barrier	Managerial Tenure	n	$\bar{X}$	SH_x	VAR.K.	K.T.	K.O.	F	P
Family Obligations – Responsibility for Childcare	Up to 10 years	78	3.50	0.50	Inter-group	0.587	0.196	0.714	0.550
	11 - 20	27	3.57	0.63	Intra-group	9.861	0.274		
	21 – 30	12	3.17	0.31	Total:	10.448			
	Over 31 years	3	3.85	-					
	Total:	120	3.49	0.51					
Economic Reasons	Up to 10 years	78	3.32	0.60	Inter-group	0.221	0.074	0.244	0.865
	11 - 20	27	3.26	0.45	Intra-group	10.873	0.302		
	21 – 30	12	3.32	0.27	Total:	11.094			
	Over 31 years	3	2.85	-					
	Total:	120	3.30	0.53					
Social Reasons	Up to 10 years	78	3.08	0.71	Inter-group	1.404	0.468	1.155	0.340
	11 - 20	27	3.51	0.37	Intra-group	14.593	0.405		
	21 – 30	12	3.00	0.47	Total:	15.997			
	Over 31 years	3	3.00	-					
	Total:	120	3.17	0.64					
Work Environment	Up to 10 years	78	3.20	0.55	Inter-group	0.742	0.247	0.671	0.576
	11 - 20	27	3.22	0.77	Intra-group	13.274	0.369		
	21 – 30	12	2.80	0.54	Total:	14.016			
	Over 31 years	3	2.80	-					
	Total:	120	3.16	0.59					
Other Reasons	Up to 10 years	78	3.56	0.46	Inter-group	0.011	0.004	0.020	0.996
	11 - 20	27	3.57	0.23	Intra-group	6.816	0.189		
	21 – 30	12	3.58	0.55	Total:	6.827			
	Over 31 years	3	3.66	-					
	Total:	120	3.57	0.41					

Total work experience and age influence women's advancement opportunities and their ability to transition from administrative to operational managerial roles, as women tend to remain stagnant in positions and departments where they have been present for several years.

To assess women managers' perceptions of career barriers and their overall managerial work experience, one-way ANOVA analysis was employed (Table 8).

The analysis results indicate that there is no significant difference between the scales of career barriers and overall managerial experience ($p>0.05$).

Table 9. Relationship between Career Barriers and Level of Education

Title of Career Barrier	Level of education attained	n	$\bar{X}$	SH_x	VAR.K.	K.T.	K.O.	F	P
Family Obligations – Responsibility for Childcare	High school	3	2.57	-	Inter-group	1.641	0.547	2.235	0.101
	College 180 ECTS	21	3.77	0.43	Intra-group	8.808	0.245		
	College 240 ECTS	87	3.43	0.51	Total:	10.448			
	Postgraduate studies +300 ECTS	9	3.71	0.24					
	Total:	120	3.49	0.51					
Economic Reasons	High school	3	3.00	-	Inter-group	2.156	0.719	2.894	0.049
	College 180 ECTS	21	3.28	0.24	Intra-group	8.938	0.248		
	College 240 ECTS	87	3.39	0.54	Total:	11.094			
	Postgraduate studies +300 ECTS	9	2.52	0.29					
	Total:	120	3.30	0.53					
Social Reasons	High school	3	3.00	-	Inter-group	0.039	0.013	0.029	0.993
	College 180 ECTS	21	3.19	0.63	Intra-group	15.958	0.443		
	College 240 ECTS	87	3.17	0.69	Total:	15.997			
	Postgraduate studies +300 ECTS	9	3.22	0.19					
	Total:	120	3.17	0.64					
Work Environment	High school	3	2.60	-	Inter-group	2.740	0.913	2.916	0.047
	College 180 ECTS	21	2.82	0.82	Intra-group	11.276	0.313		
	College 240 ECTS	87	3.31	0.50	Total:	14.016			
	Postgraduate studies +300 ECTS	9	2.60	0.20					
	Total:	120	3.16	0.59					
Other Reasons	High school	3	3.33	-	Inter-group	0.610	0.203	1.177	0.332
	College 180 ECTS	21	3.42	0.55	Intra-group	6.217	0.173		
	College 240 ECTS	87	3.64	0.37	Total:	6.827			
	Postgraduate studies +300 ECTS	9	3.27	0.41					
	Total:	120	3.57	0.41					

The one-way analysis of variance (ANOVA) used to examine the relationship between the reasons for career barriers among women managers and their level of education revealed a statistically significant difference ($p < 0.05$, Table 9). Specifically, the results indicate that the

attained level of education significantly influences the career barriers stemming from the work environment and economic factors.

The examination results of the correlation between the reasons for career barriers among women managers and their monthly earnings (Table 10) reveal a statistically significant difference between the level of personal income and the barriers emerging from the work environment ($p=0.027<0.05$).

Table 10. Relationship between Career Barriers and Monthly Earnings

Title of Career Barrier	Monthly Earnings	n	$\bar{X}$	SH_x	VAR.K.	K.T.	K.O.	F	P
Family Obligations – Responsibility for Childcare	Up to 1000 BAM	9	4.14	0.28	Inter-group	1.643	0.548	2.238	0.100
	1000-1500 BAM	36	3.55	0.67	Intra-group	8.806	0.245		
	1500-2000 BAM	12	3.28	0.11	Total:	10.448			
	Over 2000 BAM	63	3.40	0.42					
	Total:	120	3.49	0.51					
Economic Reasons	Up to 1000 BAM	9	3.76	0.81	Inter-group	1.892	0.631	2.467	0.078
	1000-1500 BAM	36	3.02	0.53	Intra-group	9.202	0.256		
	1500-2000 BAM	12	3.17	0.24	Total:	11.094			
	Over 2000 BAM	63	3.41	0.47					
	Total:	120	3.30	0.53					
Social Reasons	Up to 1000 BAM	9	3.44	0.38	Inter-group	0.295	0.098	0.225	0.878
	1000-1500 BAM	36	3.11	0.80	Intra-group	15.702	0.436		
	1500-2000 BAM	12	3.25	0.78	Total:	15.997			
	Over 2000 BAM	63	3.15	0.56					
	Total:	120	3.17	0.64					
Work Environment	Up to 1000 BAM	9	3.86	0.61	Inter-group	3.111	1.037	3.424	0.027
	1000-1500 BAM	36	2.85	0.57	Intra-group	10.905	0.303		
	1500-2000 BAM	12	2.95	0.64	Total:	14.016			
	Over 2000 BAM	63	3.27	0.51					
	Total:	120	3.16	0.59					
Other Reasons	Up to 1000 BAM	9	4.05	0.50	Inter-group	0.840	0.280	1.684	0.188
	1000-1500 BAM	36	3.51	0.50	Intra-group	5.987	0.166		
	1500-2000 BAM	12	3.41	0.67	Total:	6.827			
	Over 2000 BAM	63	3.56	0.25					
	Total:	120	3.57	0.41					

5. CONCLUSION

Women have come to recognize that financial independence is essential for personal autonomy. Sharing family responsibilities goes beyond simply dividing household tasks; it's about sharing power, with economic power being fundamental. Anxiety about balancing motherhood and family obligations is a significant obstacle for women managers. This leads to a conflict known as Work-Family Conflict, where work demands interfere with family obligations, and vice versa, causing stress and exhaustion. Finding help with childcare and housework can increase household expenses, impacting women managers' careers. However, this can also lead to a positive effect known as Work-Family Enrichment, where balancing work and family life improves well-being and personal satisfaction.

The findings of our research on invisible barriers, particularly regarding the glass ceiling in women managers' careers, highlight that the obstacle of "family responsibilities and childcare" is rated the highest. This underscores the issue of the double burden women often face. They are expected not only to fulfil their business obligations but also to maintain their commitment to family and household chores. Despite women's increasing presence in the labor market and their gradual advancement, they frequently find themselves juggling both professional and domestic roles. As a result, childcare and family responsibilities disproportionately affect women, hindering their advancement to higher positions and incomes.

Career barriers in the work environment and economic factors significantly vary based on the level of education and overall work experience. Women managers with a total work experience of up to 20 years perceive more career barriers than those with extensive work experience. Additionally, career barriers in the work environment notably differ based on the level of monthly personal income. Women managers at the early stages of their careers with lower monthly earnings perceive more career barriers compared to experienced women managers with higher personal incomes.

The presented results underscore that the primary reason for the glass ceiling among women managers is "family responsibilities and childcare." To break the glass ceiling, regulations must be enacted to share the responsibility for childcare. State and private institutions implementing various measures such as opening more childcare facilities, implementing flexible working hours, remote work, etc., would significantly aid in redistributing responsibilities among employed women managers.

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SOLUTIONS FOR IMPROVING THE INTERACTION BETWEEN INVESTMENT AND PERSONAL DATA SECURITY

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Abstract: This study examines the intricate relationship between investment processes and personal data security, highlighting the significant concern among investors regarding the handling of their personal information. With a growing awareness of data misuse, investors are increasingly cautious about where and how they disclose their personal information. This research employs a mixed-method approach, integrating quantitative surveys with qualitative expert interviews to assess how concerns over personal data security influence investor behavior and decision-making in financial investments. The findings reveal that the demand for personal information notably dampens investors' enthusiasm to engage with financial products, affecting both their investment choices and their trust in financial service providers. The study underscores the urgent need for investment firms to adopt more transparent and secure data handling practices, including the implementation of two-factor authentication (2FA), data encryption, anonymization techniques, and the principle of data minimization. By addressing these concerns, the study proposes actionable strategies for bolstering investor confidence and fostering a secure investment environment. This work contributes to the understanding of the critical intersection between investing and data security, offering insights into improving investor relations and enhancing data protection measures in the financial sector.

Keywords: Investing, data security, behavioral impact in investing, data protection strategies, process improvement.

1. INTRODUCTION

Personal data includes names, identification numbers, location data, online identifiers, or elements specific to a person's physical, physiological, genetic, mental, commercial, cultural, or social identity (GDPR, 2023). According to Hellman (2020), investing is the process of providing funds for companies that produce both profit and social value. Investment, according to Hochstadter and Scheck (2014), is the exchange of financial resources for a financial gain. Large volumes of data can be gathered, manipulated, and shared thanks to modern technology and internet access. According to Schwartz (2004), consumers are frequently ignorant of increasingly complex techniques used to obtain personal data. According to a 2019 United States survey, 62% of participants stated that it is hard to conduct regular financial transactions

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without allowing businesses to collect personal data (Pew Research, 2019). For customers, this may be quite stressful. 1 in 4 Americans are asked to agree to a privacy policy every day. Up to 79% of clients expressed concern about how businesses use their personal information. It's not just customers who are impacted by this statistic: according to a different survey, two-thirds of consumers globally feel that technology companies have too much control over the personal data they gather (YouGov, 2021). According to selected data from the "Customer Privacy Survey", 47% of customers have terminated relationships with companies due to personal data privacy policies (Cisco, 2021). In an experiment to determine how emotions influence clients' willingness to invest when given a choice between a safe and risky option, Bosman and Winden (2010) discuss the choice problem. It was discovered that clients' financial choices were influenced by their emotions. The presented conclusion highlights the possibility of improving market prediction through an understanding of investor behavior and psychology. Thus, it can be inferred from the experiment's findings that attitudes toward investments can be influenced by feelings related to the handling or security of personal data.

2. LITERATURE REVIEW

Investors may experience severe emotional reactions to risks associated with the protection of their personal information. The worry that their personal information will be misused is one of the key risk factors keeping investors from disclosing personal information. According to a national data survey conducted in the United States in 2022, 23% of investors fell victim to financial investment fraud (FTC, 2023). Furthermore, a report released in 2023 by the European Data Protection Supervisor underscored the critical nature of personal data security in the financial sector in 2023 (EDPS, 2023). The process of making investment decisions may be impacted by this. Investors might, for instance, be more likely to select investment goods or services that demand less private information. A study done in 2021 revealed that 25% of European Union citizens have serious concerns about their data. Risk considerations and legitimate concerns about the protection of personal information in the investment industry can have a big influence on investor behavior. Private information gathering and use has the potential to damage investor confidence, as noted by Goldfarb and Tucker (2018). Girard (2020) emphasizes that one major issue facing the investment industry is data protection. For these reasons, creating data protection policies and processes is essential to guaranteeing legal compliance as well as the security of investors' private information. Inadequate data handling has the potential to seriously harm investors, how they approach investments, and financial service providers in the event that the data is compromised. As a result, it is critical that financial institutions take action to protect customer information and foster investor confidence. Investment providers must identify any potential gaps in the process and seek out solutions in order to support a secure and dependable investing procedure. Current procedures and technologies for data collection and storage should be an essential component of the investment process, as investment providers gather information about investors, compile their profiles in order to meet regulatory requirements, and offer them tailored investment options. As per IBM's 2019 Cost of Data Breach report, 3% of data breaches from which data was extracted were encrypted, meaning that the data could not be misused. This suggests that data encryption is one of the most effective ways to lower the cost of a data breach. Another crucial tool for protecting privacy is data anonymization. According to the Deloitte report, anonymization is a GDPR-compliant and practical way to protect data in databases (Deloitte, 2022). Knowing that their personal data is de-identified before being processed might make customers more willing to invest. Apart from encryption and anonymity, two-factor authentication (2FA) serves as an additional safeguard against unapproved access. According

to Anyiam and Rehmani (2006), two-factor authentication is a security mechanism that combines biometrics and password strength to significantly boost security. Owing to the growing volume of data, employing tools that guarantee efficient data backup and recovery is efficient. This is supported by a survey conducted in 2022, in which 80% of participants said that backup and disaster recovery were the main priorities and solutions for the IT department (Spanning Cloud Apps, 2022). The security measures listed above aid in ensuring that private information is shielded from potential breaches. As per the European Union Agency for Fundamental Rights (2020), a study conducted in 2021 revealed that 25% of the population in the EU is extremely concerned about their data privacy. Furthermore, research conducted at the company and customer levels by Martin et al. (2017) demonstrates that possible security flaws have a negative impact on businesses, including poor stock returns, unfavorable customer behavior, and information fabrication. For these and related reasons, investors might be more likely to choose services that enable data anonymization or to restrict the information they provide to only what is necessary. The fear that individuals unrelated to the investment may obtain access to their personal data influences investors' desire to maintain privacy. Customers worry that unknown individuals might use their information for fraudulent or identity theft, or for their own personal gain (Bruner, 2018). Personal beliefs or past experiences with improperly handled personal data breaches can contribute to the development of this mindset. The main method of gathering data is through customer-filled personal data forms. Nevertheless, a number of investor complaints draw attention to incomplete or inaccurately recorded forms, miscommunication between the customer and the consultant, or a failure to verify the accuracy of the forms and provide clarification. A report on data breach investigations has also identified the factor of human negligence: according to Verizon (2023), human error and information misuse accounted for 74% of recorded data breaches. Investor mistrust is exacerbated by ineffective and erroneous data documentation. Investment providers have control over the gathering and storing of data, which is a crucial step in the investing process. Investor security and privacy may be threatened if they select incorrect data management tools or carry out inadequate processes, which could include technological flaws and human error.

3. RESEARCH METHODOLOGY

A mixed research methodology comprising both quantitative and qualitative research was chosen as the research approach. The quantitative research was conducted using a questionnaire method, while the qualitative research was based on an expert survey. A mixed method was used to better understand investor behavior and identify the factors that most contribute to feelings of insecurity because it would be difficult to explain how investor behavior relates to individual attitudes and beliefs using only quantitative and qualitative research. A 2013 study by Hashemi and Babaii found that researchers are becoming more likely to conduct their research using a mixed method approach. This demonstrates how employing a mixed method yields more trustworthy results and enables a more thorough examination of survey data than would be possible with a single research method. In this study, the qualitative study aided in understanding the expert opinions and experiences, while the quantitative study offered a statistical framework and forecasted trends. Qualitative research provided a better understanding of investor anxiety, while quantitative research helped determine the frequency and severity of these responses. By combining statistical data with professional insights, this mixed method produced a more accurate and thorough picture of the study findings. The adult population of Lithuania in 2022 served as the study population. The following information and formulas were utilized in the context of a quantitative study to establish the necessary study sample. This translates to 2,600,000 individuals (Official Statistics Portal, 2022). The source

states that it is estimated that 43% of all people make investments in Lithuania (European Commission, 2023) Probability that investors are reluctant to disclose personal information: According to the source, there is an approximate 11% chance that investors are "afraid about the security of their money or personal data." (Swedbank, 2022). The study's confidence level, is determined by the sample calculation formula, is 95%. Based on this knowledge, the study sample size was calculated using Paniotto's formula:

$$n = \frac{1}{\Delta 2 + \frac{1}{N}} \quad (1)$$

Based on the data, a quantitative study involving 79 respondents was required to obtain statistically significant conclusions. In order to guarantee dependability, the respondents' responses were gathered in an anonymous manner, enabling them to freely share their thoughts without worrying about being identified. An examination of literature sources was done to ensure that the questionnaire's questions matched the goals and subjects of the investigation to verify its validity. To ensure the research's reliability, a small sample of respondents 5% were used to test the research instrument. This helped to weed out any potential errors or ambiguities in the questionnaire or other research tools. In a qualitative study, experts in the financial sector were interviewed in a semi-structured manner to examine investors' concerns and potential risk factors for data security. There were ten open-ended questions on the survey. Ten specialists in personal data security were questioned. The content analysis method was applied to the data processing. In order to ensure the anonymity of the interviewees, the experts were coded from E1 to E10. Experts were chosen based on a set of criteria that included having at least three years of experience in the financial industry, as well as analytical and investment data security abilities. There were 26 questions on the questionnaire for the quantitative study. Open-ended questions, yes/no choices, and a Likert scale were used as question choices. The mean (μ) was calculated for data analysis. For yes and no questions, the answers were given as a percentage. The mean values of the survey responses, rated from 1 to 5, reflected investors' fear of personal data security, where 1 represents high fear or concern and 5 low. A random sampling technique was employed to select survey participants from the financial sector's investor base. The data analysis method employed in the study was descriptive statistics.

4. RESEARCH RESULTS

42% of males and 58% of females participated in the quantitative survey. 47% of respondents were aged between 25 and 34 years old, with 68% having a university degree. 31% of respondents had investment experience in equities, 27% invested in Investment Funds and 20% in virtual currencies. In a quantitative study examining trust in investment providers, 68% of respondents were negatively affected when data collection processes require a larger amount of personal data compared to other products or services on the market (μ=2,3, Max=4). This suggests that the extent of data collected impacts investors' decisions. Additionally, 23% of respondents were unaware that their data was being collected during the investment process, indicating a lack of knowledge about data management policies. This lack of awareness can lead to mistrust, possibly due to unknown risks associated with data security policies, as 42% of investors reported being unfamiliar with such policies (μ=3, Max=5). This explains why, according to 35% of respondents (μ=2,3, Max=4), they have reacted negatively when asked for personal information. It's interesting to note, though, that 46% of respondents claimed that knowing the data protection policy well would allay their worries about data security (μ=3,1, Max=5). When it comes to investor trust in investment providers when granting consent to

process personal data, 40% of respondents (μ=2,8, Max=5) expressed low trust, while 47% (μ=2,6, Max=5) expressed high concern about the security of personal data (Figure 1).

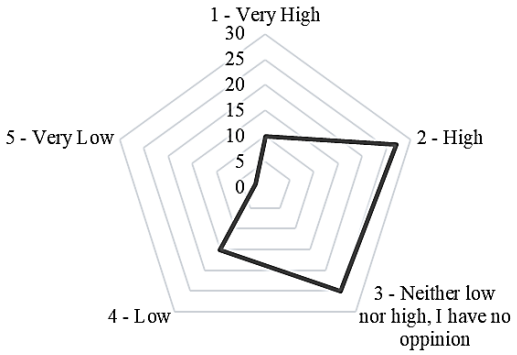

Figure 1. Concerns about the security of personal data

38% of investors stated that data collection, in the investment process, has an impact on their willingness to invest (μ=3,1, Max=5). These results show that the effect of fear to disclosure personal data exists and affects decisions to invest in financial products. When looking at how investors are affected by data collection requests, 53% of respondents said it to have a negative effect for their willingness to invest (μ=2,5, Max=5) (Figure 2).

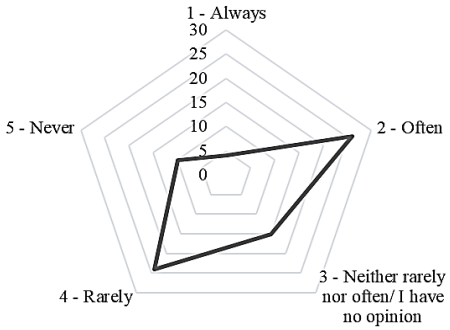

Figure 2. Impact of personal data requests on willingness to invest

Investors admitted to choosing investment products or services on the market that require a smaller amount of information, compared to other products or services on the market - 48% (μ=2,3, Max=4) (Figure 3).

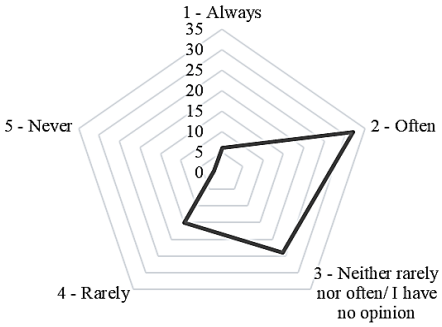

Figure 3. Tendency to choose services that require less personal information

Additionally, when employed in the investing process, respondents said that encryption, anonymization, and 2FA boost their trust. Of those surveyed, 76% expressed favorability toward 2FA (μ=4, Max=5), 73% toward anonymization (μ=3.8, Max=5), and 57% toward

encryption (μ=4, Max=5). This shows that investing confidence may be increased through the use of technology tools. 75% of investors said they believed that there is not enough protection for personal data against cyberattacks, and 65% said they thought regulatory bodies did not guarantee adequate data security in the financial sector. Furthermore, 10% of participants disclosed having personally experienced a data breach incident. Further examining the feeling of insecurity, 73% of the respondents said that they are afraid of personal information being used illegal activities, for example for fraud or identity theft, one third of respondents emphasized that they always have this fear (μ=2,2, Max=5). 58% of investors expressed feeling insecure about their data being backed up (μ=2.4, Max=5). This is intriguing because, despite the fact that backups are a tool for data protection, it's likely that investors believe that having copies of personal data lessens that protection. Investors are worried about the security of their personal data and have little faith in the data collection procedures, according to a quantitative study on customer attitudes toward providing it when investing in financial products. Investors have expressed that data negatively affects their desire to make investments and may lead them to use anonymized data or disclose only the information that is absolutely necessary. The study's findings indicated that certain investors had expressed ignorance about the fact that their data was being gathered while they were making an investment. This suggests that investors are not sufficiently informed about data management policies, nor are businesses doing enough to draw attention to them. The majority of participants expressed a lack of confidence in investment providers, particularly when requested to divulge more personal data than other investment service providers.

Experts expressed concern about potential data breaches, identity theft, fraud, and cyber threats during the qualitative research survey. They also shared their thoughts on the primary risk factors and potential areas for improvement. Experts revealed that they experienced anxiety about personal data when making investments prior to beginning their work in data security. This may also suggest that, in order to reduce mistrust, it's critical to understand the motivations behind data collection. Experts stressed that investors might not know why collecting personal data is required because they don't often investigate the motivations behind it. Emphasizing that investors may decline to provide information and, as a result, not invest if the process for gathering data is too onerous or complex. The investors may feel more confident if the procedure is effective and professional. The potential for data to be accessed by outside parties or contracted businesses was also underlined, emphasizing improper employee conduct and unapproved person access. Experts also acknowledged that, depending on the company's policy, the effectiveness of the current data security measures can occasionally be partially ineffective (Table 1).

Table 1. A negative view of data collection in the field of investment.

Subcategory	E1	E2	E3
A negative view of data collection in the field of investment	*They are often understaffed and lack expertise."*	*"It could be argued that it is redundant anyway; balance is often required."*	*"... state regulatory authorities ... should actively monitor and demand the implementation of high security standards."*
	E4	**E5**	**E6**
	"Of course not!" regulators do not punish companies in any way..."	*"...the attitude of the state regulatory authorities ... is rather passive..."*	*"The regulator often acts in the presence of a leak to impose fines, so I think that data protection is not ensured."*

Effective security measures encourage customers to invest and make them feel more secure. 6/10 experts said that they believe that regulatory authorities play an insufficient role in

overseeing data security. Experts advised educating staff members about safe handling of personal data and making sure clients are aware of data collection and security procedures in order to reduce these dangers. Experts stressed the need to guarantee fair use of data and expressed worry about possible illegitimate uses of company data. Investing in IT solutions and taking precautions against potential hacks was recommended by numerous experts. Additional strategies put forth by experts included raising customer awareness of data security, implementing new technologies, bolstering physical and digital security systems, and updating data on a regular basis. The use of 2FA and the significance of GDPR compliance were emphasized (Table 2).

Table 2. Improving the security of personal data collection

Subcategory	E1	E2	E3	E4	E5
Improving the security of personal data collection	*"Use 2FA authenticators"*	*"Comply with GDPR Guidelines"*	*"...restrict new hires' access to data."*	*"Update technologies related to personal data security"*	*"...constantly keep updating the data security best practices" ...seek to know who has access to their customer data from third-party service providers...know how this data is handled by the service providers themselves"*
	E6	**E7**	**E8**	**E9**	**E10**
	"Take preventive measures against possible hacks."	*"Invest in IT solutions that ensure data security."*	*"Invest in your software"*	*"Implement data audits."*	*"...strengthening physical and digital security, regular training and raising awareness among customers about the importance of data security"*

Investment firms were urged to make sure that their clients are fully informed about how their data is used and that it is done in a way that complies with the law. Customer loyalty and trust could both rise with knowledge about how personal data is processed. New hires should only be granted access to personal information under rigorous guidelines with a business purpose in mind. Third-party service providers should also receive special consideration. The amount, location, and type of personal data that businesses gather should all be under the active supervision and enforcement of regulatory bodies, which should also periodically review and tighten data security-related laws. More severe sanctions should be applied, and violating organizations should be forced to upgrade their data security infrastructure and make necessary investments if improper processing of personal data is found.

5. CONCLUSIONS

Study has shown that investors to be distrustful and concerned about the security of their personal data while investing. Investors said that data collection in the investment process has a negative impact on their willingness to invest by encouraging investors to use anonymized data or provide only necessary information when investing. The results of the study showed that some investors said that they did not know that their data was being collected during the investment process, which shows that investors are not familiar enough with data processing policies. Most respondents indicated a low level of trust in investment providers, especially when asked for a larger amount of personal information than other market providers. Clear

communication and understanding of data protection could enhance investor confidence during the investment process. Investment firms should use data fairly and transparently to boost customer confidence, complying with laws, informing investors about data storage, and training employees in proper data processing. Strengthening IT systems and data security measures, such as encryption, anonymization, and 2FA, is essential for building investor trust and reducing customer fears. In order to manage backup copy concerns, businesses should concentrate on reducing data storage. Regulations pertaining to data security should be strengthened, laws should be clarified, and penalties for privacy violations should be more severe. Proper handling of personal data can help investment service providers retain their reputation and investor trust, according to an analysis of the relationship between investment and personal data security. For this reason, to foster investor confidence, financial institutions must take steps to guarantee the security of personal data.

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OPERATIONAL RISK OF ACCOUNTING DIGITALIZATION

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Abstract: Automation of accounting is a trend which requires deep research to mitigate possible risks and to make legal background for standardization. On the real sample of 10 SMEs from Slovakia, we have investigated possibilities of implementation of automatic processing of received invoices including automatic AI solutions capable to withdraw relevant data from an invoice and import withdrawn data into accounting software for further processing. There are several available solutions capable to perform the task. By evaluation of possibilities for small SMEs we came to the conclusion that such solutions are possible and may be viable even for SMEs. As automation of processing received invoices may be viable for SMEs, it can become an industry standard. This research also shows that in Slovakia current accounting act prevents implementation of accounting automation based on AI due to not considering possible error rate caused by such automation.

Keywords: Accounting, digitalization, Operational risk, management.

1. INTRODUCTION

Accounting digitalization and automation is the current trend (Rada et al., 2023) aiming to fully replace accountants by a form of an artificial intelligence solution (Kommunuri, 2022). Occupation of an accountant is considered as one of the most endangered by an artificial intelligence (Tokic, 2018). Introduction of an artificial intelligence accounting bears several concerns, processes and legal questions which must be solved first (Song et al., 2014). Using any form of accounting automation requires to use accounting data, including digitalized accounting documentation. Paper accounting documentation is not suitable for AI based automated accounting despite of some form of automated accounting is possible using accounting data only. For legal purpose, audit purpose and regulatory purpose, accounting documentation which corresponds to the accounting records must be easily accessible. The use of digitalized accounting documentation is essential for the accounting digitalization, especially for companies processing significant amounts of accounting records.

Automation of accounting can be handled in two levels: 1. Automation of repeating operations (Holmes & Douglass, 2022); 2. Automation of accounting general. While the first

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level of automation requires automation of accounting based on algorithms, the second level require adoption of an artificial intelligence capable to evaluate data while processing the data, and capable to provide required outputs (Kommunuri, 2022).

In Slovakia, there are currently several solutions available on the market capable of automated reading and processing of invoices (Vlčko & Melchuovà, 2023). These solutions are based on AI neural network solutions (Tumpach et al., 2020). Applying any of these solutions and connecting it to the accounting software provides environment capable to receive, proceed, and account any received invoice of a standard, repeating, business operation of an investigated company (Chyzhevska et al., 2021). While the processed received invoice is from a supplier who regularly supplies to the company, the only necessity is to verify whether the invoice is justified. There are several possible solutions such as reconciliation of invoices to orders or any other similar logical reconciliation to a company operation. In small companies this could have been done by an accountant who knows the company operation and is capable to verify whether received invoice is justified. In larger companies with several divisions or locations an automatic verification solution shall be implemented, otherwise a human intervention would be necessary. Similarly, if an invoice of a not regular operation is received there have to be implemented process of verification whether the invoice is justified. If the company has the power, considering its market significance, it can dictate to its suppliers to use dedicated gateways to deliver invoices. Such solution can be used for implementation of automatization of verification whether the invoice is justified. Small companies are not able to require its suppliers to use dedicated business correspondence digital gateways. Small companies just have to receive invoices by standardised correspondence forms such as email, cloud, post etc. Government can require using dedicated digital gateways to deliver the invoices which is capable of implementing automated verification of justification of invoices. Legal requirement to use dedicated governmentally controlled gateway for all standardised business correspondence such as invoices have been proposed in Slovakia by accounting act novelisation draft (PI/2021/6 Predbežná informácia k návrhu zákona o zasielaní údajov finančnej správe z faktúr daňových subjektov. slov-lex.sk, n.d.). Due to significant number of notes to this novelisation draft, the draft has been withdrawn. Nevertheless, automation of accounting starts with automation of processing received accounting documents. The chart of receiving accounting documents in order to proceed them automatically is shown in the Figure 1. Once the data from the received documents is imported the process of automated accounting could be implemented in place. Automatic accounting solution must be able to proceed the operation correctly to avoid misconduct or misinformation to the users of the accounting information (Francis & Schipper, 1999). In Slovakia, improper accounting can be penalised up to 3 milion € (Act No. 431/2002 Z. Z. on Accounting, 2002). Accounting act in Slovakia does not apply materiality threshold for automated accounting as it does not cover automatic accounting at all, therefore any, even immaterial error is considered as breach of the accounting act and may be subject of penalisation. This example shows that not only technical capabilities are subject of consideration but also operational risk including legal risks must be considered when accounting automation is being implemented.

Automation of accounting does not come without a cost (AlNasrallah & Saleem, 2022). Implementing costs, operational expenses of automated accounting and risks must be considered in comparison to the current human operated accounting expenses. Human operated accounting expenses are represented mostly by wages. In this paper, the research is focused on possibilities of automated accounting for small SMEs which are already established on the market, and which has their operations well established already. In comparison a start-up which does not have its processes yet established or well stabled it might be easier to start its

accounting operation as automated from the very beginning. SMEs represent 99,5% of all business in Slovakia (OECD, 2020).

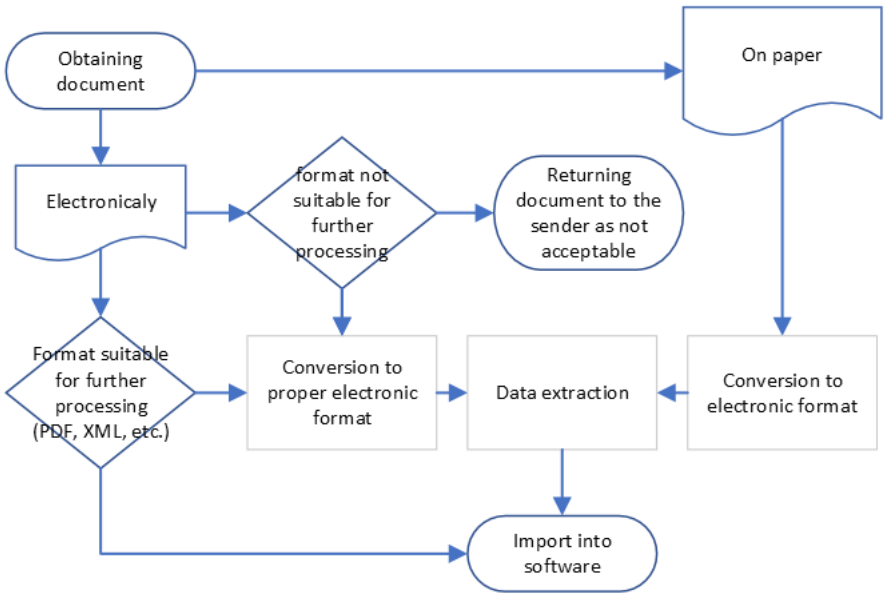

Figure 1. Process of obtaining accounting document for further automated accounting (Own processing)

As the human driven accounting is well established, the processes, risk and standardised terminology are well described (Agostino et al., 2022), when researching the automation solutions of accounting, the possible bias shall be mitigated. Replacing humans by machines, robots or AI in general is a sensitive issue which widely exceed possibilities of publication in this paper and exceed possibilities of our research. Even thou, it is essential to mention that labour market in Slovakia in recent years shows higher demand than supply of available human accountants. As the trend swells for several years now and have not been affected by Covid-19 crisis and considering the demographic trends in Slovakia (Vaňo, 2019), and in Europe in general, it does not seem to change. Due to lack of accountants on the labour market (Vlčko & Meluchovà, 2022) and legal requirement to perform accounting for every company regardless its size or volume (Act No. 431/2002 Z.z. on Accounting, 2002; Vlčko & Meluchovà, 2021), it is natural that missing accountants must be replaced somehow by machine-driven solutions to avoid reduction of companies on the market.

2. METHODOLOGY OF RESEARCH

On a random sample of 10 SMEs from Slovakia we evaluate possibilities of automation of accounting in 1st level – automation of repeating accounting operations. The sample have been taken randomly. Data have been provided by an accounting company with condition to secure anonymity of evaluated companies in order to protect business secrets. To evaluate volume of repeated accounting operations we reduced research to evaluation of the number of received invoices. There are usually also other areas in companies which could be evaluated such as number of issued invoices, number of monthly salaries, etc. These could be matter of further research papers. Every company operates in specific environment dealing with specific issues. Therefore, it is impossible to generalize the approach to every company. Dealing with received invoices, issued invoices and employees is common for every company. In Slovakia

not all companies are required to account a warehouse through the year. Only audited companies are required to account warehouse through the year (Act No. 431/2002 Z.z. on Acounting, 2002). All other companies can voluntarily account a warehouse through the year. In this sample no company book the warehouse through the year, so this agenda is not investigated in this research. By analysing market available solutions, we have evaluated possible application of automated solutions of importing received invoices data gained by AI processing of the invoices and automated relevant information extraction from an invoice. No matter whether the accounting software itself is capable to extract data form the invoices, every accounting software is capable to import data from another source via standardised data bridge. This research shows that regardless of the accounting software in use, the process of automated data extraction is technically possible and financially viable to implement even for small SMEs.

Risk assessment of automated invoices data extraction have been caried. Out of the possible risks, there has been identified three currently highest probable risks: Erroneous data extraction without recognition results to incorrect financial statements; Penalisation for breach of accounting act if an unrecognised error occurs; digital data archive corruption or breach of data protection. All of these risks could be mitigated applying proper measures. Each of these risks could result into bankruptcy if penalised according to current legislation in place in Slovakia. Despite of advantages of automation invoice extraction and automation of accounting in terms of expense savings, the risk management is necessary to avoid possible loses. Therefore, this research shows that not only expense savings shall be considered, but also risk management is necessary to be considered when a company considers implementing accounting automation in any form or any stage.

2.1. Sample overview

Average number of accounting documents in 2020 is shown in Table 1. Every company is different. Some issue many invoices, others issue few invoices. There are companies which issue zero invoices, and their revenues are being gained by retail cash operations.

Table 1. Number of accounting documents in the sample companies (own processing)

Company	Accounting records	Received invoices	Issued invoices
a	3615	343	0
b	8435	220	171
c	10743	787	1138
d	4320	316	12
e	5002	342	10
f	1976	12	5
g	2473	207	126
h	4423	162	0
i	6314	452	0
j	99	11	1

Information of issued invoices is only for better overview of the sample. As the process of issuing the invoice is being done in the same ERP as the accounting, the issued invoice is a product of more complex operations which as performed in the same system can be made automatically or semi automatically.

3. RESULTS AND CONCLUSION

Invoices from suppliers are being received to the company by email in PDF, by a gateway in PDF, by post in paper form or by paper form together with the supplied goods. If the invoice is being received electronically in PDF format, it can be automatically forwarded into the software capable to withdraw relevant information out of the PDF. If the invoice is received in paper format, it must be scanned first. Scanning of invoices require human intervention always. Scanning of paper invoices can be implemented into already established process in the company, for example: invoices can be scanned right at the reception desk immediately as received. If received together with goods, the invoice can be scanned right at the moment of receiving goods either by warehouse employee or by a lory driver, depending on who from the company receives the goods first. Received paper invoices can be verified whether they are justified right at the process of scanning by a person who scan an invoice. The digitally received invoices must be verified for justification by an automatic verification process. This research shows that the process of automation of processing received accounting documents is possible and viable even for SMEs with low turnover and low volumes of accounting documents. As the prices of available solutions are decreasing due to competition, automation of processing of received invoices may become an industry trend or an industry standard. Automated extraction of received invoices and following automated processing saves salary expense which affects possible government salary tax revenues. Automation in general, not only in accounting, is sensitive topic which shall be solved broadly across the industries with consideration of possible risks. Automated processing of received invoices can become standard only when proper legislation would allow so, including consideration, evaluation, and possible correction of possible error rate. Accounting automation, especially using AI capabilities, technically predate legal environment. Lack of legal guidelines and barriers results in operational risks for the companies which implement such solution. For developers, lack of proper legislation implies uncertainty whether developed solutions would be profitable. AI capabilities without proper legal environment may be misused to overturn aims of original accounting acts goals. Wide implementation of accounting automation shall also include adaptation of IFRS (IFRS Accounting Standards, 2022) and IFRS for SMEs (International Financial Reporting Standard for Small and Medium-Sized Entities (IFRS for SMEs), 2015) to new accounting processes, challenges and risk coming from automation. Lack of accounting automation standards may result in financial disadvantage for those pioneers who later would be forced to change their pioneering processes due to new accounting automation standards if the accounting automation standards would be once released.

Once it would be standardised, legally covered, to avoid human accountant to proceed a received invoice, the legal questions and risks must be properly mitigated. For now, the further research is needed and welcome to help mitigate possible risks of implementation of accounting automation solutions for companies. Academic research shall provide outputs to legislation makers and accounting standards setters to set up proper standards for the safe sustainable business environment.

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Original research

ECONOMICS AND ENVIRONMENTAL-HEALTH RISK ASSESSMENT FOR SUSTAINABLE DEVELOPMENT OF THE GOLD MINING INDUSTRY IN NIGERIA

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Abstract: Though the gold mining industry potentially generates employment and increases Nigeria's foreign exchange, the crude practices of artisanal miners often exacerbate environmental degradation and health hazards. Hence, humans face health risks when excessively exposed to the heavy metals released during gold mineralization. This study, therefore, adopts a descriptive approach towards suggesting a comprehensive economic evaluation and risk analysis for managing the impact of gold mining industry sustainably and bearing in mind people's health that should equally be managed in a healthy and sustainable manner. A review of existing Environment-Health Risk Assessment (EHRA) studies on gold mining areas in Nigeria reveals that the estimated risk quotients are generally above recommended limits consequent upon inadequate enforcement of mining precautions. This study, therefore, argues that incorporating EHRA studies and considering economic costs and benefits of mining could provide an objective benchmark for managing various estimated health risk quotients and returns from more gold mining. For Nigeria's, harnessing opportunities in the gold mining industry requires interdisciplinary drive that seeks to incorporate environmental-health risks into optimization of gold mining industry. Appropriate policy interventions will be expedient for gold mining industry to be less harmful and not constitute direct threat to sustainable development in Nigeria.

Keywords: sustainable development, health risk assessment, gold mining, Nigeria.

1. INTRODUCTION

Throughout history, gold has held a position of value. The precious metal determined the value of currencies during the gold standard system, and it is still in high demand due to its ostentatious value. For resource-rich nations, the gold mining industry could be very important. In addition to the potential revenues the industry yields, countries endowed with gold could benefit as the precious metal is considered a safe haven asset and provides a hedge against global uncertainties as was seen during the COVID-19 pandemic (KPMG, 2021). The gold mining industry, therefore, could contribute to Nigeria's development.

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Although Nigeria has not fully harnessed the inherent opportunities in gold mining due to desertion of mines by colonial mining firms, inadequate funding, poor infrastructure and dependence on crude oil (Van Vuuren, 2019), the increased exploitation of gold raises concerns that gold deposits could be extracted sub-optimally or even exhausted, and that gold mining activities negatively impact on the environment. In the last few years, the government has been making attempts to regulate the industry, especially because of its revenue potential. However, regulations and policy considerations have not sufficiently incorporated assessments of the health impacts of the environmental degradation resulting from gold mining (Oke et al., 2020).

Human activities often leave the environment at a loss, and gold mining is a salient case study. Across gold-endowed nations, and especially in Nigeria, studies highlight that gold mining significantly contributes to the contamination of the soil, water bodies, plants and rocks with heavy metals such as copper, zinc, arsenic, cadmium, mercury and lead (Eludoyin, et al., 2017; Tun et al., 2020; Adewumi, & Laniyan, 2021). People are, therefore, predisposed to health hazards when they are overly exposed to these heavy metals, especially when the elements are ingested or inhaled above certain limits (Adewumi, et al., 2020).

In a bid to achieve sustainable development of the Nigerian gold mining industry, a comprehensive assessment approach is needed. While economic and value-creating prospects exist, environment-health risks must also be checked. In itself, sustainable development encompasses the economic, environmental and social dimensions of sustainability as well as the key elements underpinning sustainable development: people, planet, prosperity, peace and partnership (United Nations, 2015). Several studies have, therefore, made attempts to consider the across-the-board impacts which gold mining exerts, quantifying the health risks traceable to the resulting environmental degradation. While the increasing regulations of activities impacting the environment have seen economic analyses on environmental health policy increase over the years, Phelan (1998) argued for more economic perspectives to influence these policy directions. Hence, this paper highlights that economics is vital in the assessment of the Nigerian gold mining industry, and provides insights into accounting for the negative externalities on the health of people living around artisanal/subsistence mining settlements and policy responses to mitigate the hazards induced by gold mining in Nigeria.

2. LITERATURE REVIEW

Economics is widely recognised because of its applicability to a diverse range of issues and phenomena. Since humans are constantly faced with multifaceted and complex problems, collaborative and interdisciplinary research to resolve these issues has been on the increase. Economics has been pivotal to many of these studies; finding expression in issues bordering on health, education, energy, law, governance, and physics among others. Thus, sufficient grounds for assessing the gold mining industry's drive towards sustainable development through the "economics lens" exist.

Economists see risk reduction as producing utility or satisfaction to people, and these benefits are captured by the willingness of people to pay to get the accompanying satisfaction from reduced hazards. While risk assessment methods could help in quantifying risk, economics goes further by trying to evaluate the benefits of risk reduction in monetary terms (Dockins et al., 2004). For instance, the revealed preference approach and the stated preference approach among other developments in the economics literature have been adopted to estimate the values individuals place on lower likelihoods of experiencing health hazards from environmental contamination (Lichtenberg, 2010).

Economics also plays a significant role in quantifying the costs of environmental health policies. The concept of opportunity cost stands out for economists, and it is often used in

estimating the cost of interventions since it provides a more realistic outlook of what was lost as a result of the policy action. From the perspective of reducing health and environmental hazards due to gold mining, economics asks the question "At what cost was this risk reduction achieved?" After denominating both costs and benefits in the same unit, evaluating the trade-offs then becomes possible and an informed decision between alternative lines of action can be made. This is the economics angle, and as Hammitt and Robinson (2021) put it, it is the "essence of decision analysis" (p. 559).

The growing concern about environmental sustainability as well as the potential consequences of environmental degradation on life of the people have also stimulated efforts in quantifying risk. Contributions to the literature have bordered around health risk assessment, ecological risk assessment and comparative risk assessment. Since the pioneering efforts of the United States Environmental Protection Agency (EPA) in the 1970s, several environment-health risk assessment (EHRA) frameworks and EPA's projects have been deployed across countries. The frameworks are meant to understand how human activities influence the environment, characterise the health effects of environmental factors and pollutants, and identify and assess policies available for curbing toxic substances. (Cristofaro & Jones, 1988). Specifically, EHRA is defined as "the process of estimating the potential impact of a chemical, physical, microbiological or psychosocial hazard on a specified human population or ecological system under a specific set of conditions and for a certain time frame" (Department of Health and Aged Care, 2012, p. 3). It yields a perception of the potential benefits of policies aimed at reducing health risks from exposure to toxic substances. When properly conducted, environment-health risk assessments wield quality evidence which is often useful in directing environmental health policies. Particularly, EHRA often requires field surveys due to the context-specific behaviours and responses of different populations to different pollutants (Urban Sanitation Development Program, 2014). While EHRA provides estimates of exposure to risk, policymakers still have to make a decision on what level of risk that can be tolerated.

Since its conceptualisation in the 1987 report by the World Commission on Environment and Development, sustainable development has been widely appreciated and pursued across nations. As defined in the report, sustainable development is the "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, 1987, p.54). Furthermore, the principles of sustainable development embrace economic development, environmental sustainability and social well-being. Thus, for a nation or an industry to develop on a sustainable path these three dimensions of sustainability must be ensured.

Among the key elements of sustainable development is "people" (United Nations, 2015). There is no sustainable development if the basic needs of people in the present generation and those unborn are unmet. Some of the sustainable development goals (SDGs) are aimed at ending poverty and hunger and promoting good health and well-being, and this resonates with people. Along with the concerns for the environment and planet, the health of people is at the heart of sustainable development. More so, the environment places demands on the health of people living within it. Hence, efforts towards achieving sustainable development can be considerably measured from an assessment of the environmental-health implications of such interventions.

The gold mining industry is not inconsequential, at least for two reasons. Firstly, the employment and revenue generation drive for the economy of Nigeria. Secondly, the potential environmental and health consequences from its unregulated and improper extraction and processing. Thus, concerns are often raised about the unsustainable extraction of non-renewable natural resources such as gold to the detriment of future generations (Hotelling, 1931). The gold mining industry can, therefore, promote or obviate sustainable development in Nigeria.

While a significant number of environment-health hazard assessment studies of gold mining in Nigeria suggest a negative outlook on indices that are essential for sustainable development, some studies have downplayed the risks, especially when the mining is done observing adequate precautions. Notably, artisanal mining could cause water pollution, derailing Nigeria's progress towards achieving SDG 6: Clean Water and Sanitation, and SDG 14: Life Below Water. In addition, studies have found evidence of soil degradation in active and abandoned gold mining areas, hurting farmlands, causing stunted growth in plants, and threatening food security (Eludoyin et al., 2017; Bello, 2022). This impinges on SDG 2: Zero Hunger, while also worsening SDG 3: Good Health and Well-Being and SDG 15: Life on Land.

On the other hand, the Nigerian government could generate considerable foreign exchange and tax revenue from promoting activities and attracting investments into the gold mining industry. The previous administration in Nigeria implemented regulations and development which was hoped to create 250,000 jobs while generating $500 million from royalties and taxes of gold trade (Reuters, 2020). If achieved, this could spur the nation towards achieving SDG 8: Decent Work and Economic Growth, and SDG 1: No Poverty, while the revenue could be used to strengthen infrastructure and invest in human capital. The gold mining industry, thus, needs to be properly monitored, ensuring that the environmental impacts of mining are managed, with the remediation of affected areas while investing the gains from the sector to improve other dimensions of sustainable development.

On the conduct of assessments for sustainable development, arguments have ensued in the economics literature. While earlier studies made use of data from conventional national accounting, the neglect of the environment in such calculations motivated developments including the integration of the adverse health effects of environmental quality degradation with economic accounting by Bartelmus, et al., (1991). Indices like the World Bank adjusted net savings which accounts for environmental degradation have also been used, bearing strong evidence that the economics lens are not self-sufficient and that health and environmental concerns have to be taken into consideration (Koirala & Pradhan, 2020; Oyeranti & Obijole, 2023).

Economics-environment-health risk assessment (EEHRA) harnesses the strengths of both approaches. Environmental experts and toxicologists can effectively deploy their scientific risk assessment tools for dose-response estimation and exposure assessment. On the other hand, economics deploys tools in valuing environmental benefits, establishing probabilities and discounting based on the preferences of the affected individuals (National Environmental Health Partnership Council, 2016). A cost-benefit analysis tracks streams of costs and benefits over time, and since the utility people derive from future risk reduction is less than the utility from immediate risk reduction; it is important to factor in the time value of risk reductions. In addition, environmental problems involve uncertainties, behavioural changes, sunk costs and sunk benefits – issues that the concept of opportunity cost and developments in behavioural economics could help capture (Phelan, 1998; Johnson & Slovic, 1998).

3. METHODOLOGY: CONTENT ANALYSIS APPROACH

3.1. Profile of the Gold Mining Industry in Nigeria

Along with vast amounts of crude oil and natural gas reserves, Nigeria is endowed with solid minerals including gold, iron ore, coal and bitumen. Nigeria's gold deposits are mostly found in the present-day northwestern and southwestern regions of the country notably Maru, Anka, Malele; Tsofon Birinin Gwari and Kwaga, Bin Yauri, Gurmana, Okolom-Dogondaji, Iperindo (Kankara & Darma, 2016). Although, the global oil price shock of the 1970s saw

increased attention on crude oil extraction, the mining and trade of solid minerals had begun many decades before – during the colonial period. From 1914, gold mining began in Northern Nigeria, and in the 1940s, alluvial mining began in Western Nigeria. While production of gold increased with the discovery of new mines, mining has not been sustained over time as most of the miners operated on a small scale (Falola, 1992; Van Vureen, 2019).

Gold mining in Nigeria has also been fraught with issues around illicit mining, smuggling and environmental degradation. Since mining could be done using the hands, it provided an incentive for people to mine gold illegally and sell it to goldsmiths, destroying several acres of arable farmlands in the process (Falola, 1992). In addition, the government lost royalties as much of the gold mined was not declared and illegal markets for gold thrived especially with the high demand for gold in Western Nigeria. The government, therefore, adopted several ordinances and regulatory policies on gold traders and miners.

In more recent years, there has been rekindled interest in developing the gold mining industry to achieve economic diversification, generate more revenue for the government and curb illegal mining (Reuters, 2020). While 1.51 tonnes of gold was produced in 2020, it is estimated that Nigeria still has 600,000 tonnes of untapped alluvial and primary gold deposits (Oxford Business Group, 2023). With large-scale investments and improved regulatory oversights, the potentials are realisable as non-crude oil mining activities only accounted for a meagre 0.6% of the GDP in 2021 (Central Bank of Nigeria, 2022). Since the launch of the Presidential Artisanal Gold Mining Development Initiative (PAGMDI) in 2019, one large-scale mining operator has been attracted, two gold refineries have been licensed, and developments have been made towards creating gold buying centres and taxing gold trade (KPMG, 2021; Reuters, 2020). It is hoped that these developments can have positive trickle-down effects on the Nigerian economy.

4. FINDINGS AND DISCUSSION

4.1. Gold Mining Industry-Induced Environment-Health Hazards in Nigeria

Since gold has been relatively expensive and coupled with the high demand for gold in the southwest, the discovery of gold in Ilesha triggered the “gold rush” in the 1940s (Falola, 1992). Many people began illicit artisanal gold mining to earn income for their households, contaminating the environment with toxic heavy metals in the process. This destruction of the environment negatively impacts the health of the miners and people living within the neighbourhood. More so, unregulated artisanal mining in Nigeria increases the severity of the risks involved as gold ores are often extracted, handled, stored and transported without precautions (Oke et al., 2020).

Heavy metals associated with gold mining in Nigeria include arsenic, cadmium, nickel, lead, copper, zinc, cobalt and mercury (Adewumi et al., 2020). Meanwhile, these toxins build up in plants and animals and can damage the brain, kidney, liver, and bone marrow as well as increase the likelihood of blood and respiratory infections in humans when ingested through food in excessive amounts. For example, several cases of childhood lead poisoning traceable to gold ore processing were confirmed across villages in Zamfara State between May and September 2010. Lo et al. (2012) investigated the health effects of lead poisoning over the period and found that, in ore-processing villages, there were more infected children under the age of 5 years in addition to significantly higher risks of death from convulsion. A scientific study on the Anka gold mining area of Zamfara also confirmed a significant accumulation of heavy metals in the nails and hairs of children due to lead poisoning (Adewumi et al., 2020).

Beyond lead poisoning, studies have also confirmed that gold mineralisation has polluted water bodies, significantly increasing the risk of exposure to arsenic and mercury (Lo et al., 2012; Adewumi & Laniyan, 2021; Nurfadillah & Maksum, 2021). Nonetheless, a few studies have argued that artisanal gold mining in Nigeria does not pose considerable environmental radiation risks and, hence, has little threat to human health (Adebayo et al. 2022). Indeed, Garba et al., (2021) confirmed in their study across areas in Zamfara by comparing the terrestrial radiation dose measurements with the world average, that illegal mining did not exacerbate the health risks. Similarly, Adebayo et al. (2022) found moderate health risk quotients from exposure to elements from the Ife-Ijesha gold mining area in southwestern Nigeria.

Through a number of studies on likelihood of environment-health risks, different guidelines for environment-health risk assessment have been generated. For instance, Lo et al. (2012) conducted dose-response and exposure assessments and classified the soil-lead exposure levels in affected communities of Zamfara using the US EPA recommendations. It was on the basis of EHRA that their study confirmed the higher risks to children in settlements along gold mining areas. The human health risk assessment conducted by Oke et al. (2020) found that the concentration of chromium was beyond safe levels in the Epe gold mining area and contributed to increased cancer risks for people with prolonged exposure. Taiwo & Awomeso (2017) found same for Ijeshaland gold mining areas. Bello et al. (2022) also arrived at the same conclusion that cancer burdens were higher for onsite dwellers in gold mining areas after comparing risk estimates derived using RESRAD meaning RESidual RADiation and ERICA that is a software system that with a structure based upon the tiered ERICA Integrated Approach to assess the radiological risk to terrestrial, freshwater and marine biota (assessment computer programs with the US EPA acceptable limits).

4.2. Management of Gold Mining-Induced Environment-Hazards in Nigeria

Environment-health risk assessment (EHRA) guidelines are often engaged in analysing the likelihood that humans experience health hazards due to environmental degradation occasioned by activities such as gold mining. EHRA studies are often conducted by pure scientists including toxicologists, geologists, geochemists, and environmental and public health experts. Their findings and risk quotients are, thus, often expressed in scientific notations. While it is essential to base policies on scientific and rigorous evidence as provided in such studies, incorporating economic evaluations of the cost and benefit of proposed risk reduction policies will help in deciding on optimal policies to pursue. Importantly, economics plays a vital role in providing monetary valuations of risk reduction policies (Dockins et al., 2004). A National Environmental Health Partnership Council (2016) report, for instance, that every $1 invested in national and state-level health programmes yielded $71 in asthma-related cost savings. This finding was arrived at from economic evaluation studies, providing a benchmark for weighing the loss from environmental damage to realisable gains.

Though outside the context of gold mining, a health economic evaluation of atrial fibrillation screening in mitigating cardiovascular diseases in Nigeria by Jacobs et al., (2021). Using Quality of Life Adjusted Years (QALY) and comparing with the cost of atrial fibrillation screening, this study showed that screening was cost-effective in reducing health burdens. Mulder et al. (2022) also compared the monetary values of the benefits and costs of using a new drug in treating drug-resistant tuberculosis across Nigeria, Indonesia and Kyrgyzstan. In Mexico, Evans et al., (2021) adopted this interdisciplinary approach to quantifying the mortality benefits and costs of implementing diesel retrofits to improve air quality.

5. RECOMMENDATIONS AND CONCLUSION

As the Nigerian government seeks to generate more revenue from regulating gold mining activities, economic management can be deployed to identify and evaluate policies that will yield better welfare outcomes and engender sustainable development. The findings can also guide in crafting an appropriate pollution tax which simultaneously curbs environmental degradation. As externalities are well studied in economics, efficient market-based mechanisms could be implemented to prevent overproduction and promote environmentally and socially friendly practices. Economic assessments in the Nigerian context could, therefore, help in mitigating the risks emanating from gold mining. Policies could be highly potent in influencing the needed and required changes in systems that will be sustainable development compliant for Nigerian gold mining industry.

First, regulations of artisanal and small-scale gold miners and traders should be strengthened. Beyond licensing gold miners and ensuring tax compliance, safety standards should be prioritised while on the gold mines as well as offsite: from the extraction stage to the mineralisation and processing of the gold ore, and to waste management procedures. Since small-scale artisanal gold miners are prone to breaching safety measures to cut operation costs, stringent monitoring should be done by regulatory agencies as well as proper communication and education on the environment-health risk.

Secondly, while the regulation of gold mining companies increases, the firms should also be encouraged to produce sustainability reports documenting their efforts in promoting sustainable development. As extractive firms often impact the environment negatively, efforts to mitigate the harmful impacts and promote sustainable development are beneficial. Mining companies could adopt newer technologies to reduce and properly manage the toxic wastes generated during their operations. As being practised by crude oil firms, gold mining firms should be urged to promote the development of their local communities through environmental remediation efforts and contribute to investments in human capital, especially health care and education. Several other policy measures could also be deployed to reduce the resulting environmental damage including retrofitting plant and equipment with environmentally friendly technologies, designing pollution permits, and levying pollution taxes on gold mining companies.

The gold mining industry could be a “gold mine” in spurring Nigeria’s progress towards sustainable development as the government seeks to generate foreign exchange, tax revenue and employment from scaling up investment in the sector and regulating artisanal mining. It could, nonetheless, constitute a drag on sustainable development due to the accompanying environmental degradation and health hazards resulting from excessive exposure to the heavy metals released during gold mineralisation. In Nigeria, water bodies and soils are often polluted with heavy metals including arsenic, cadmium, nickel, lead, copper, zinc, cobalt and mercury, resulting in cognitive disorders and other morbidities. As such, environment-health risk assessment (EHRA) guidelines have to be followed as best practice to quantify the health risks posed by elements with adverse health effects.

While several EHRA studies have been conducted on the health hazards around gold mining areas in northwest and southwest Nigeria, the risk reduction quotients reported in these scientific studies are often difficult to comprehend by non-technical audiences and policymakers. Expressing risk reduction benefits in monetary terms, using economic evaluation and cost-benefit analysis based on EHRA studies, will undoubtedly guide policies aimed at promoting the sustainable development of the Nigerian gold mining industry. This paper, therefore, calls for more research on economic evaluation and risk analysis of policies that could

harness the potential of Nigeria's gold mining industry with little and insignificant environment-health risks.

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WORKFORCE WELLBEING MANAGEMENT LEVERAGING SEMANTIC KNOWLEDGE GRAPH

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Abstract: Workforce wellbeing is of strategic importance in new economy, not only for enterprises but for SMEs as well. Fatigue is one of key factors which affect workforce wellbeing, particularly in risk-sensitive environments such as manufacturing. Despite that importance of fatigue is identified in literature, this aspect is not much leveraged in existing solutions aiming high levels of effectiveness by optimal operation planning and scheduling. In this paper, a solution aiming optimal fatigue-aware planning and scheduling in manufacturing based on semantic knowledge graphs is presented. Thanks to adoption of ontologies, our approach enables seamless integration of heterogeneous data sources including legacy ERP systems, external services as well as sensors such as IoT wearable devices. Complementing the planning and scheduling solution, two additional apps are developed: 1) mobile app for physiological data acquisition using wearable device for purpose of fatigue estimation 2) shopfloor monitoring web app with machine operation instructions incorporated.

Keywords: workforce wellbeing, welfare, ontology, semantics, fatigue, planning and scheduling, knowledge graph.

1. INTRODUCTION

Healthy and productive workforce is a vital asset for any organization, as it drives success and fosters positive reputation. Hence, employers aim to create a workplace environment that promotes workforce wellbeing, leading to increased job satisfaction, lower turnover rates, and improved productivity (Bennett et al., 2017). Workforce wellbeing covers mental, emotional, and physical health of employees on a workplace. Additionally, it also involves the adoption of supportive environment which allows individuals to thrive both personally and professionally. Therefore, employers are increasingly recognizing the strategic importance of workforce wellbeing, not only as a moral imperative but also as a key factor in business success.

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Well-rounded approach to workforce wellbeing includes several components (Bennett et al., 2017; Tshering, 2022): 1) *mental health support* - involves providing resources for managing stress, anxiety, and other mental health challenges; 2) *work-life balance* - promoting a healthy balance between work and personal life, which can be achieved through flexible work arrangements, remote work options and other policies that encourage taking time off when needed; 3) *physical health and fitness* - encouraging physical activity and healthy habits can have a significant impact on employee wellbeing, so the employers can offer fitness programs, gym memberships, or on-site exercise facilities, as well as promote healthy eating options in the workplace; 4) *positive workplace culture* – adopting inclusivity, respect, and open communication, so the employees can feel valued and heard; 5) *professional development and growth* - offering opportunities for learning and career advancement can boost employee morale and wellbeing, which employers can support by providing training programs, mentorship, and clear pathways for career progression; 6) *social connections and team building* - building strong social connections among employees can enhance workplace morale and overall wellbeing, which can be facilitate through activities such as team-building and other social events 7) *recognition and rewards* - recognizing employee achievements and providing rewards for outstanding performance can boost morale and encourage a positive work environment.

On the other side, fatigue represents critical factor affecting workforce wellbeing and productivity (Gempur, 2024). It is often described as feeling of weariness, tiredness or lack of energy (NIOSH, 2024). Therefore, it can impact an individual's ability to perform tasks efficiently, make decisions, and maintain a positive outlook. Despite that fatigue management importance and effects in manufacturing are identified (Islam at al., 2015; Shuling, & Hall, 2021), not many works in the existing literature actually incorporate it for purpose of more efficient planning (Tao et al., 2024).

Therefore, in this paper, we propose a solution leveraging ontologies and semantic knowledge graph which enables seamless integration of heterogeneous data sources (ERPs, IoT devices) for purpose of fatigue-aware manufacturing planning and scheduling. The main goal of such approach is to make use of fatigue information together with other aspects related to manufacturing resource availability - not only to reduce the probability of risks for injuries and damages within the manufacturing area, but also increase the wellbeing of manufacturing workforce, which could bring additional benefits – such as increased productivity and higher worker satisfaction. Additionally, we adopt similar approach of semantic-based data integration for purpose of manufacturing monitoring with two goals in mind – from both manufacturing manager and worker perspectives. For manufacturing managers, it would give better overview of the current worker and equipment state, so they can act accordingly – re-schedule tasks to the workers and generate updated work plans. On the other side, for the workers, we aim to provide educational value and reduce cognitive load, leveraging the integration with machine operation instructions.

2. BACKGROUND AND RELATED WORKS

2.1. Semantic knowledge graphs

Semantic knowledge graphs represent a dynamic approach to organizing and understanding information, which does not capture only the key entities (such as people, places, or concepts), but also the relationships between them, providing a rich and interconnected view of data relevant to the domain of interest. Entities are represented as graph nodes, while edges are used to denote the relationships between them. Unlike traditional databases, semantic graphs use a flexible schema, which gives possibility for more adaptable and context-sensitive

representation of knowledge. This kind of flexibility is achieved through ontologies, which define the types of relationships and entities, allowing for semantic reasoning and inference against such data representations.

There are several benefits of using such representation (Sharma, 2021): 1) *contextual understanding* – as relationships are explicitly defined, semantic knowledge graphs can capture context in a way that flat data structures cannot. This context is crucial for applications that require deeper insights into complex data and its further usage; 2) *interoperability and integration* - semantic knowledge graphs can integrate data from diverse sources, making them ideal for large-scale data aggregation and analysis, facilitating interoperability by using standards like RDF (Resource Description Framework) and OWL (Web Ontology Language); 3) *enhanced search and querying* - queries in a semantic knowledge graph can traverse relationships and extract complex patterns, leading to more nuanced and meaningful results 4) *inference and reasoning* - semantic knowledge graphs support inferencing, allowing new knowledge to be derived from existing data through logical rules, which is valuable for applications like expert systems and knowledge-based AI.

In our past works, we have successfully adopted ontologies and semantic technology in several scenarios for purpose of IoT data integration. In (Nejkovic et al., 2020), coordination based on IoT sensing devices in robotics experimental environment leveraging LiDAR and temperature values was achieved. On the other side, we used similar approach for IoT-based indoor localization system data integration in (Tosic et al., 2023).

The approach in this paper relies on proprietary Tasor ontologies for representation of various aspects related to manufacturing, such as machines, workers, their skills, materials, resources, work orders and the activities (Tosic et al., 2023). This kind of representation enables within unified semantic knowledge graph represented with respect to ontologies enables establishing interoperability, covering legacy Enterprise Resource Planning (ERPs), external services (such as machine learning or prediction capabilities) and heterogeneous IoT devices (wearables and positioning devices, for example). Furthermore, our planning framework makes use of semantic knowledge representation incorporating information from various sources in order to achieve fatigue-aware work activity scheduling.

2.2. Literature review

In the existing scientific literature, there are few works in different domains taking into account fatigue for workforce scheduling. Table 1 gives overview of these solutions, together with the underlying approaches.

On the other side, the fatigue estimation method leveraged in this paper is takes into account heart rate and acceleration sensor data coming from wearable devices worn by workers. Compared to other approaches, it provides additional flexibility, as it leverages semantic knowledge graph for data integration, which enables to conveniently add new parameters (semantic integration of various measures coming from IoT devices or ERP system). This way, our approach provides additional extendibility and flexibility compared to the existing ones. Additionally, we present practical experience from using different applications developed on top of the proposed platform deployed on IoT-on premise-Cloud continuum.

Table 1. Overview of works leveraging fatigue for workforce scheduling

Reference	Description	Method	Domain
(Thorpe et al., 2017)	Selection of team players considering their fatigue level	Analysis of heart rate variability	sport
(Ranakul et al., 2024)	Scheduling of tanker employees	Bayesian networks considering various factors: ship design, age, illness, amount of sleep	shipping
(Amindoust et al., 2021)	Fatigue-aware approach, aiming personnel planning during the COVID-19 pandemic	Genetic algorithm which takes employment and surplus costs into account	healthcare
(Bowdem et. al., 2018)	Selection of truck drivers with aim to reduce the risk of accident occurrence	Alertness level-based estimation for Vehicle Routing Problem (VRP)	transportation
(Aribi et al., 2023)	Dynamic flexible job shop-scheduling problem under workers' fatigue constraints, considering three types of unexpected events: job insertion, machine breakdown and job cancellation	Multi-objective optimization in synergy with genetic algorithm	manufacturing

3. IMPLEMENTATION OVERVIEW

When it comes to implementation, we rely on the existing proprietary Tasor SCAS platform, especially for semantic knowledge graph management on backend. The proposed approach is referred to as Fatigue aware semantics for planning and scheduling in discrete manufacturing (FASPAS). Illustration showing the overview of the underlying components behind FASPAS implementation is given in Fig. 1.

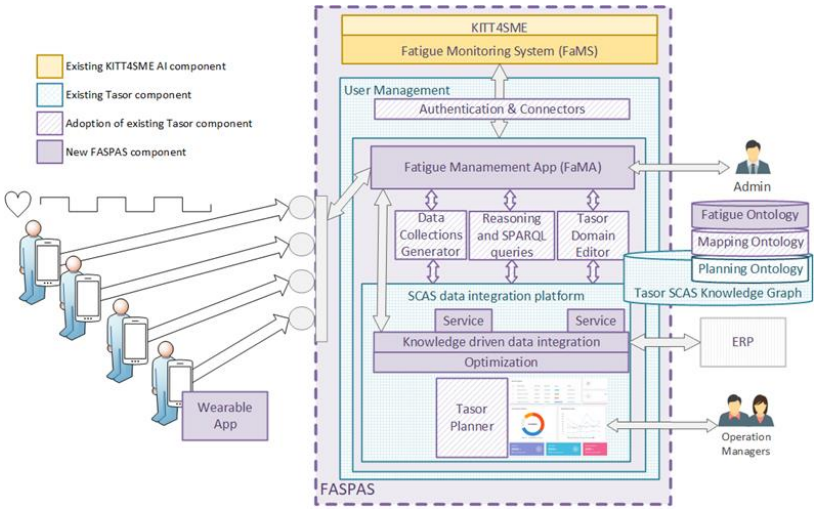

Figure 1. FASPAS implementation based on Tasor ecosystem leveraging semantic knowledge graph and ontologies

Furthermore, we develop wearable mobile applications whose goal is to acquire physiological data about employees (heart rate, acceleration). The data is collected by FAMA service that aims to further feed the Fatigue Monitoring System (FaMS) with the expected inputs. FaMS is one of KITT4SME's (KITT4SME, 2024) existing AI components which provides fatigue prediction taking into account physiological (such as heart rate) data (Rožanec et al., 2023).

Additionally, FIWARE Orion Context Broker, as part of the KITT4SME infrastructure (KITT4SME, 2024), is used for both interaction with FaMS and sensor data acquisition. For that purpose, we develop Broker Connectors Service, which provides high-level interface to data management of broker data, such as subscribing to value changes, pushing measurements, retrieval of specific values and persisting data streamed to broker. Functionalities for acquiring data from FIWARE Orion Context Broker were already introduced in (Tosic et al., 2023), but here they are extended with data persistence capabilities and customized for connecting to KITT4SME infrastructure.

On the other side, our ecosystem includes Tasor Domain Editor, which is an application for management of production resources and flows used. All reasoning in the system is based on existing efficient SPARQL query development and management tools.

The crucial ontology behind the scheduling framework is Planning Ontology, which already existed, but Mapping Ontology was extended and customized for the specific domain, while Fatigue Ontology was developed from scratch. Fig. 2 shows the segment of Planning Ontology, specifically, the part describing the concept of order.

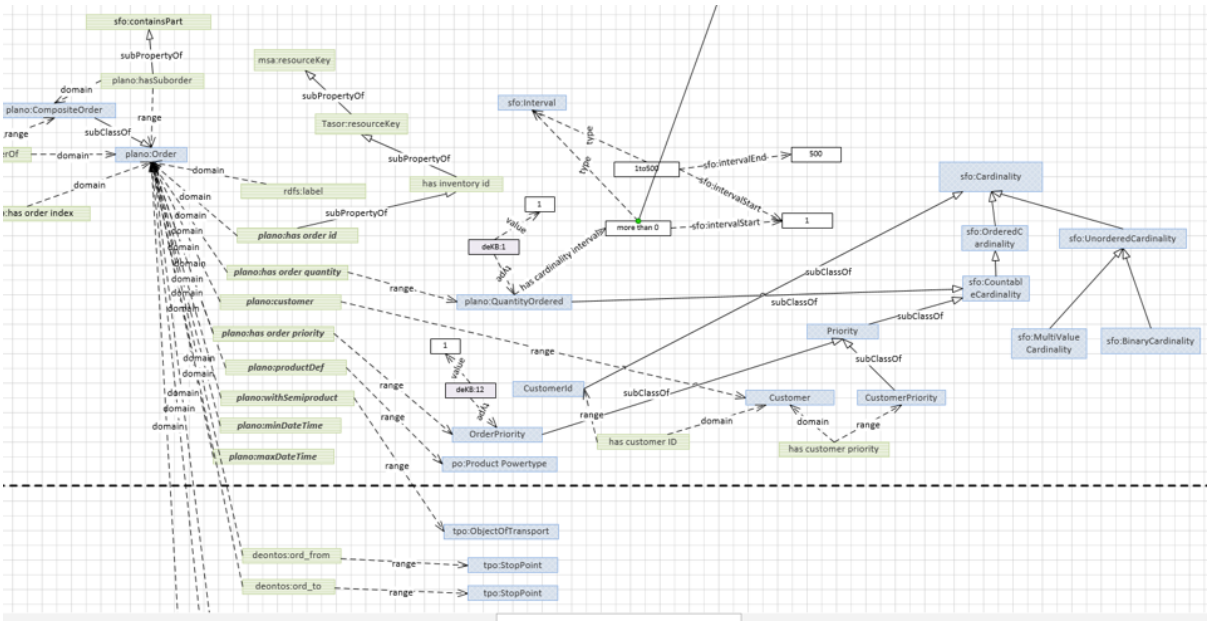

Figure 2. Segment of the Planning Ontology illustrating concept of Order

Knowledge driven data integration and optimization services were developed to connect to the existing ERP system. Finally, one of the existing Tasor Planner variants was adopted and modified accordingly to answer to requirements of the particular application, in order to generate fatigue-aware work plans based on employees' physiological data acquired by wearable devices.

Moreover, Fig. 3 shows the depiction of Fatigue Ontology. The key indicator of industrial employee fatigue monitoring domain is a Fatigue Factor, which represent an aspect which has impact on person's level of fatigue. The factors can be divided into two sub-groups – static and dynamic factors. Static factors are independent on the current circumstances and

represent long-term characteristics of an employee, which cannot be changed under the environmental factors within the usual monitoring time frame. Here, we have physical characteristics, such as height, weight and gender. Moreover, the aspects of age and working experience are also taken into account, together with maximum heart rate for that person. On the other side the dynamic factors are likely to change under various environment conditions and include worker's body temperature, movement, acceleration, galvanic skin response and current heart rate. These dynamic characteristics represent either current state of the employee's physiology or describe the activity performed itself (for instance, moving or standing) and depend on external factors, such as activity type, task difficulty, part of the day and similar. The values describing dynamic aspects are collected using various environmental sensors (like cameras, proximity sensors and air parameter sensing) or wearable devices (Polar Verity Sense in our case). On the other side, current relative position of workers given in form of *(X, Y, Z)* coordinate triplet can be taken into account, especially when it comes to the aspects of shopfloor monitoring. Additionally, the role of worker and their position within the working environment like office number/room or part of the factory together with its geographical location can be of interest as well. This factory can capture additional factors which can be used for refinement when it comes to fatigue determination, such as climate (depending on geolocation of factory) and pollution (with respect to part of the factory and types of activity performed). Finally, the level of fatigue is determined by classification-based machine learning (such as Random Forest or Deep Learning neural network) algorithms and normalized to 10-step Borg scale, ranging from 0 (no fatigue) to 10 (max).

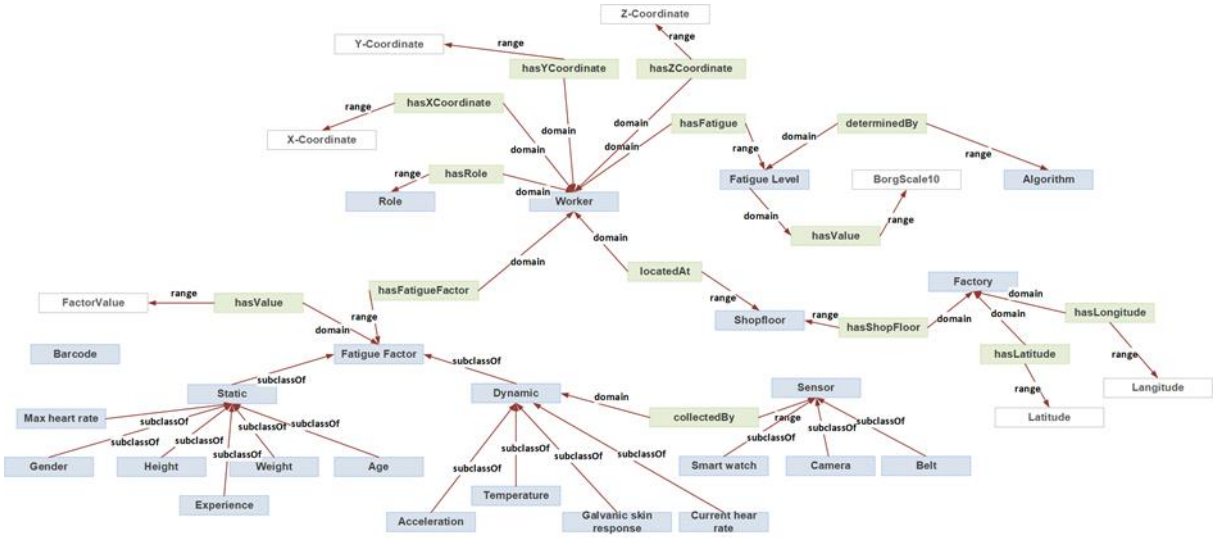

Figure 3. Fatigue Ontology

4. CASE STUDIES

4.1. Shopfloor monitoring

The goal of this case study is to provide the means for convenient shopfloor monitoring by integrating the information about workers, machines, products and other manufacturing resources thanks to semantic knowledge graph and ontologies. This way, manufacturing managers will have complete insight into the current state of manufacturing process, so additional actions can be taken in order to make work process more efficient or overcome the

unexpected events. On the other side, workers will be able to quickly get the basic information about the usage of shopfloor equipment.

For this purpose, we offer a web application which is optimized for running on mobile devices and tablets as well. Apart from ERP data, this application leverages semantic integration with indoor localization data coming from WiPos-based IoT system, as described in (Tosic et al., 2023).

It offers two main views: semantic annotation and live exploration (as shown in Fig. 4). The purpose of semantic annotation view is to give ability to the manufacturing managers to map specific locations within the shopfloor to corresponding machines available within the ERP inventory data. Apart from their basic information (machine type, name, manufacturer, set of manufacturing steps which can be completed), operational instructions can be included as well, so workers can later easily find the manual, once they come close to the machine within operation monitoring view. This way, educational value is added to our solution, aiming to reduce the risk of workers using machine with lack of expertise.

On the other side, operation monitoring provides location-based exploration of shopfloor. As user walks within the manufacturing area, their location is updated and corresponding points of interest (machines) revealed accordingly, once they come near them.

Figure 4. Shopfloor monitoring case study: a) semantic annotation b) live shopfloor exploration

Demo video showing the previously described application live in action is publicly available on YouTube[†].

4.2. Fatigue-aware planning in manufacturing

This case study has two parts. The first one is targeting workers in manufacturing. It is a self-monitoring Android mobile app which integrates sensor data (heart rate, acceleration, gyroscope and magnetometer) coming from wearable devices in order to estimate the current worker state, expressed as fatigue level. For this purpose, we make use of wearable device, which sends data to mobile app that forwards the measured values to FAMA service. Finally, FAMA service streams the measured data to FIWARE Orion Context Broker, so it can be consumed by external FaMS service and value of fatigue estimated based on these measurements. In Fig. 5, the two main screens of mobile app used by workers are shown: a)

[†] https://www.youtube.com/watch?v=ajMcmGThpYw

current physiological state – includes values of fatigue, heart rate and acceleration b) history – visual representation of critical measurements over time, while period can be specified by user.

On the other side, the second part of this case study is web app aimed to be used by manufacturing managers. It offers the following screens: a) fatigue monitoring – complete insight into current fatigue estimation for all the active workers based on wearable device data integration b) planning – generation of fatigue-aware manufacturing plan, taking into account both the measured data and ERP (worker skills, available machines, products and underlying processes). The objective of scheduling process is to allocate physically less demanding tasks to workers with higher current fatigue value and vice-versa. Apart from increased manufacturing efficiency and injury risk minimization, we aim to achieve improved workforce wellbeing and worker satisfaction as well. Illustration of case study usage from manager's point of view is given in Fig. 6. Finally, the live action showcase for this case study can be found as footage[‡].

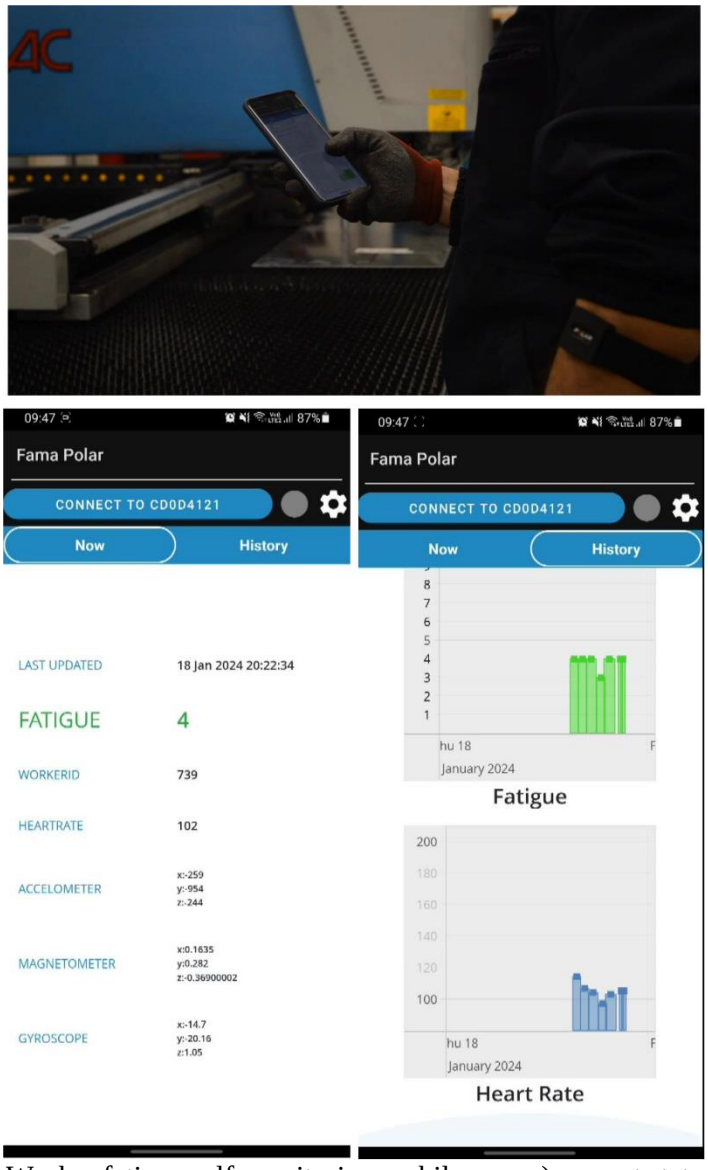

Figure 5. Worker fatigue self-monitoring mobile app: a) current status b) history

‡ https://www.youtube.com/watch?v=meBgrpsnfZg

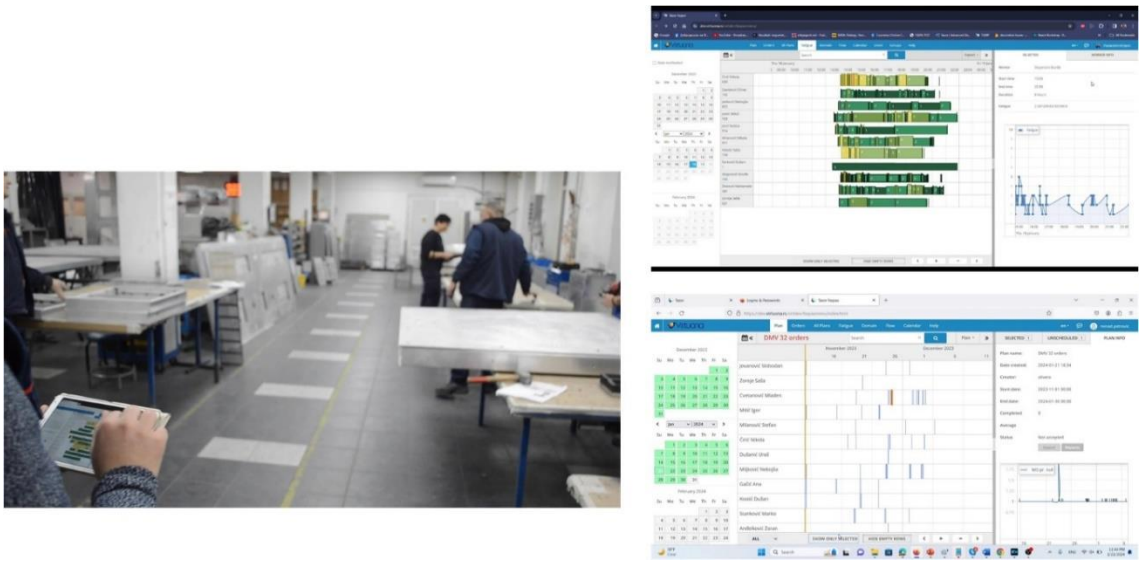

Figure 6. Manufacturing manager web app: a) fatigue overview b) planning

5. CONCLUSION

In this paper, we introduced a semantic knowledge graph-driven approach to integration of enterprise data resources – legacy ERPs and IoT devices on the other side (wearables and localization system). Moreover, such representation is further leveraged for operation planning in manufacturing scenario in order to increase the workforce wellbeing by incorporating the information about worker's fatigue among other factors. Additionally, we provide supportive mobile and web apps which would make the whole process more convenient to both the manufacturing managers and workers. According to our experience, one of the main advantages of such approach is extendibility. Representation of manufacturing knowledge in form of semantic graph gives ability to later dynamically integrate additional factors and data sources (either devices or external services). In future, we plan to explore the utilization of Large Language Models (LLMs) on top of our semantics-driven approach in order to automatize as much as possible the following steps applied on ontologies and semantic data: 1) creation of new domain ontologies starting from free-form text or tables; 2) construction of SPARQL queries starting from text 3) automatic code generation based on semantic representations.

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YOUNG CONSUMERS' INSIGHTS ON BRAND ASSOCIATION, BRAND AWARENESS, PERCEIVED QUALITY, BRAND IMAGE, BRAND LOYALTY AND BRAND EQUITY

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Abstract: Brands try to capture young consumers as they are early adopters which help them to secure business for long term. The purpose of this study is to examine the effects of brand association, brand awareness, brand image, perceived quality and the mediating effect of brand loyalty on brand equity among young consumers and their direct relationship with brand equity. Data from 75 young consumers were analysed using an open-source software named Jamovi and PLS-SEM. Empirical results via Correlation and Multiple regression authenticated that direct relation was insignificant for all the variables except perceived quality but most variables were significant in indirect relationship with brand loyalty as mediator. Overall, the model was an average fit. Perceive quality predominantly affects brand loyalty, which in turn has a significant impact on brand equity. These findings imply to marketing professionals and practitioners to aid them develop marketing strategies to amplify brand equity and gain a competitive edge to foster their business.

Keywords: Brand Equity, Brand Loyalty, Brand Association, Perceived Quality

1. INTRODUCTION

Brands with inspiring vision and clear values deliver promises and gain a competitive edge in market place. Brands initially served as means of identification to assure customers the source of quality of products. It conveyed tangible symbolic meaning along with tangible product attributes. Research on quantifying and measuring the effects of its attributes eventually led to conceptualisation of Brand equity (Oh et al., 2020). Research by some others suggest that brand equity positively and significantly influences brand loyalty (Ebrahim, 2020). While some other research works propose that brand loyalty affects brand equity positively (Sasmita & Suki, 2014) and brand loyalty, brand vocal, purchase intention ability of consumers increase positively when consumer brand equity is increased substantially (Arya et al., 2021).

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The indirect effect of brand trust, perceived quality and perceived value on brand loyalty was studied using customer satisfaction as mediator and was found to have significant effect while brand identification had insignificant relation to loyalty (Kataria & Saini, 2020). A positive perception on quality and satisfaction towards a brand is an essential antecedent for consumers to exhibit brand loyalty and when a consumer perceives that a brand is superior, the propensity to be loyal to the said brand increases (Lacap et al., 2021). According to a research (Francioni et al., 2022), brand loyalty has very strong and maximum positive impact on brand equity followed by brand awareness while perceived quality has no influence on brand equity and it was unveiled that brand awareness and perceived quality has no mediating effect on brand equity while brand loyalty has a significant mediating influence on brand equity.

Brand loyalty is not sufficiently and completely explained by itself (Kumar & Sharma, 2013; Oliver, 1999). Research suggest that perceived quality and other some variables relating brand strongly affects brand loyalty. As stated in the mentioned research works, brand loyalty affects brand equity significantly while other variables have less significant or insignificant effect on brand equity. Based on these researches, our study is designed to explore the mediating role of brand loyalty on brand equity with other variables relating to brand. The remaining paper is organised as follows. The first session discusses the theory of variables and its operation with the framework and introduces the conceptual framework to be tested. The second session elaborates the methodology of this research work. The third session presents the results of the research. Further, it discusses the implications, limitations and conclusions.

2. LITERATURE REVIEW

Jeon (2017) states that as authors mentioned earlier, a brand is a name, term, sign, symbol, design or signalling combination that is intended to identify the goods and services of one seller or group of sellers and branding has been around for decades as a means to distinguish the goods of a particular producer. He also stated that the long-term success of a brand depends on selecting a brand concept prior to market entry.

Brand associations is defined as “anything linked in memory to a brand” and also the core role of brand associations is to create meaning for consumers (Till et al., 2011). He also stated that they help consumers process and retrieve information and can help differentiate or position the brand and if the associations are positive, they will create beneficial attitudes and feelings and provide a reason to buy. The higher the brand associations in the product, the more likely it will be remembered by the consumer and the commercial value that derives from consumer perception of the brand name of a product can be exploited effectively (Sasmita & Suki, 2014).

Brand awareness is related to the strength of brand node or trace in memory, which we can measure as the consumer’s ability to identify brand under different conditions and it is the ability of a potential buyer to recognize or recall that a brand is a member of a certain product category (Patil, 2017). Brand awareness has direct effects on brand’s equity (Pouromid & Iranzadeh, 2012).

Brand image is defined as ‘reasoned or emotional interpretations of a brand, which are influenced by marketing activities and consumer characteristics’. It is an overall impression carried by a brand in the form of thoughts related to the advertisements of the product, use of the product and attributes of the product (Joshi & Garg, 2021). Brand image has significant positive effects on brand loyalty (Alhaddad, 2015). A favourable brand image represents customers’ positive perception toward a brand and it plays a key role to create positive brand equity fundamentally (Momen et al., 2019).

Perceived quality is a bundle of attributes in comparison with the consumer's expectations and is also defined as the consumers' judgment about an entity's (service's) overall excellence or superiority (Snoj et al., 2004). Perceived quality has significant positive effects on brand loyalty (Alhaddad, 2015). Perceived quality influences brand loyalty as well as brand equity (Palomba, 2022).

Brand loyalty is defined as a deeply held commitment to rebuy a preferred product/service consistently in the future, thereby causing repetitive same-brand or same-brand-set purchasing, despite situational influences and marketing efforts having the potential to cause switching behaviour (Le, 2020). Brand loyalty describes "the attachment that a consumer has to a brand" (Lou & Xie, 2021). Aggregate brand loyalty was a positive predictor of brand equity (Palomba, 2022). Brand awareness/associations and brand loyalty positively influence brand equity (Francioni et al., 2022).

In accordance with a study (Anselmsson et al., 2007), Brand equity comprises a number of dimensions, which the brand owner can develop, manage and control. Brand equity is the value endowed by the brand to the product. It originates from the brand name, and not only physical attributes. It is a relative measure, that must be compared to relevant competitors. It is a global impression of the value associated with a brand. Aaker (1992) defines brand equity as "a set of brand assets and liabilities which provides value to customers as well as to a firm. It is linked to the brand's name and symbol. It can subtract from, as well as add to, the value provided by a product or service". Nam distinguishes brand equity from brand loyalty by defining brand loyalty as a traditionally conceived behavioural construct relating to intentions towards repeated purchase. By contrast, brand equity entails favourable disposition that may not necessarily result in purchasing behaviour. Thus, behavioural intentions are one of the consequences of brand equity, rather than its component (Nam et al., 2011). Brand equity is the intangible asset created by marketing endeavour (Ambler, 1997). Based on the above discussions, the following hypothesis are stated,

H1: Brand association, brand awareness, brand image and perceived quality has a positive impact on brand loyalty.

H2: Brand loyalty has a positive impact on brand equity.

H3: Brand association, brand awareness, brand image and perceived quality has a positive impact on brand equity.

The conceptual diagram of the above mentioned hypothesis to be tested is as follows:

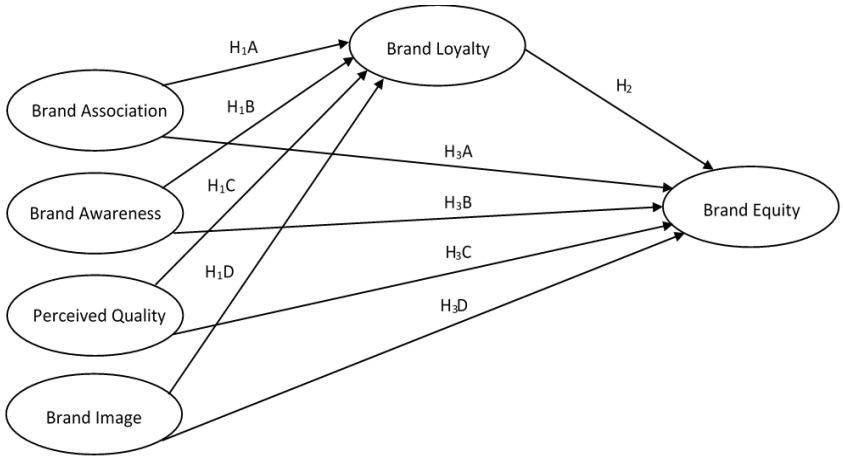

Figure 1. Proposed Model

3. METHODOLOGY

For the development of a model for the proposed framework, the following sampling techniques and data collection methodology was followed and the measures development for the questionnaire is also discussed.

3.1. Data collection

The present study is designed to study the insight of young consumers towards Shoe brands. The respondents were young adult consumers who are actively involved in online social networking and had experience in purchasing products on types of favourite shoe brands either Reebok, Adidas, Sketchers, Nike, Puma or Bata. The respondents where between the age group of 18 to 30. The study commenced with the collection of data through self-administered questionnaire through online. The questionnaires were circulated among college students. 75 responses were gathered utilizing convenience sampling technique. The present study adopted exploratory research design. This research was done to study the factors that influence `Brand Equity`. In order to test the stated hypothesis, we used quantitative approach.

3.2. Measures development

The questionnaire was structured with close-ended questions. Questionnaire was divided into 7 sections. First section included demographic profile, gender, profile, age etc. Other sections examined the factors affecting brand equity. The questionnaire items are as shown in Table.1. The survey items were adopted from current scales and likert scale ranging from 0 (Strongly agree) to 5 (Strongly disagree) were used to measure the questionnaire items. Brand equity, brand loyalty, brand image, brand association and brand awareness were measured with (Sasmita & Suki, 2014) scale and perceived quality was taken from (Severi & Ling, 2013). Data collected were analyzed using statistical techniques namely Descriptive Statistics, Regression, Correlation, SEM and Cronbach`s alpha.

Table 1. Constructs and measures

Items	Measurement Statements
Brand Association	1. I trust the company who owns the particular product/brand. 2. This particular product/ brand is familiar to me.
Brand Awareness	1. I keep track of new product launches of the particular brand. 2. I can recognise this particular brand in comparison with the other competing brand. 3. I know how this particular brand looks like. 4. I can quickly recall symbol or logo of the particular brand.
Perceived Quality	1. This particular brand provides prompt services at the promised time. 2. This particular brand handles customer complaint effectively. 3. This particular brand gives individual customer attention.
Brand Image	1. This particular brand has a differentiated image in comparison with the other brand. 2. This particular brand has a clean image. 3. This particular brand is well established.
Brand Loyalty	1. I regularly refer this particular brand. 2. I usually use this product/brand as my first choice in comparison with the other brand. 3. I would recommend this brand to others. 4. I will not switch to another brand. 5. I am satisfied with brand.
Brand Equity	1. Even if another brand has the same features as this purchased brand, I would prefer to buy this brand.

4. RESULTS AND DISCUSSION

The model was estimated and interpreted for results using the Structural Equation Modelling. The descriptive statistics and correlation results were discussed and it was followed by the interpretation of direct relationship of brand awareness, brand association, brand image, perceived quality with brand equity and the mediating relationship of brand loyalty was discussed.

4.1. Measurement model evaluation

4.1.1. Descriptive statistics

Samples were statistically analyzed and it was found that 55% of the respondents were male and 45% were female. 51% of the respondents were under the age group of 21 to 25 years and 40% were under the age of 26 to 35 years. Majority of the respondents spend below Rupees 10 thousand per year on shoe products. The frequency of purchase of shoe brands in a year was less than 2 times by majority of them. Bata, Nike and Adidas got more responses for the favorite brands as shown in Table 2.

Table 2. Sample characteristics

Variables	Frequency	Percentage (%)
Gender		
Male	41	54.67
Female	34	45.33
Age		
18 to 20 years old	7	9.33
21 to 25 years old	38	50.66
26 to 35 years old	30	40
Money spent (in rupees)		
Less than 10k	43	57.33
10k to 25k	18	24
25k to 50k	7	9.33
More than 50k	7	9.33
Frequency of buying in a year		
Less than 2 times	33	44
2 to 3 times	27	36
4 to 6 times	9	12
7 and above	6	8
Type of favourite brand		
Adidas	16	21.33
Bata	24	32
Nike	20	26.67
Puma	7	9.33
Sketchers	7	9.33
Reebok	1	1.33

4.1.2. Reliability and Correlation

Pearson correlation coefficient the r symbolizes the estimate of strength of linear association and its direction between interval and ratio variables. The coefficient's sign signifies

the direction of the relationship (Chee, 2015). The results of r indicate that perceived quality, brand association and brand awareness have strong significant correlation with brand loyalty as r values are >0.5 and the correlation between brand image and brand loyalty (r=0.49) is relatively high. Hence it can be concluded that there is significant relationship between all the independent variables with brand loyalty. Secondly, comparing the r values of brand loyalty and brand equity (r=0.296), it can be inferred that there is moderate significant relationship between them. Finally, comparing the r values of brand awareness, brand association, brand image, perceived quality with brand equity. Since the r values of these variables are <0.5, it can be deduced that there is no significant relationship among these variables or the relationship is weak which is shown Table 3. These findings are in accordance with prior findings (Lacap et al., 2021; Francioni et al., 2022). The values of Cronbach's alpha were above the mentioned limit and is shown in table 4.

Table 3. Correlation Matrix

	Brand Loyalty	Brand Awareness	Brand Image	Perceived Quality	Brand Association	Brand Equity
Brand Loyalty	1					
Brand Awareness	0.59	1				
Brand Image	0.41	0.46	1			
Perceived Quality	0.62	0.68	0.58	1		
Brand Association	0.59	0.357	0.29	0.37	1	
Brand Equity	0.296	0.12	0.13	0.30	0.18	1

Table 4. Validity and reliability test

Variables	Mean	Standard deviation	No of Items	Cronbach's alpha
Brand Loyalty	2.301333333	0.70471258	5	0.674
Brand Awareness	2.143333333	0.74113378	4	0.615
Brand Image	1.688888889	0.82442688	3	0.842
Perceived Quality	2.102222222	0.782644576	3	0.834
Brand Association	2.293333333	1.075191163	2	0.83
Brand Equity	2.466666667	1.297954038	1	0.681

4.1.3. Mediating relationship

Multiple regression analysis was performed with brand loyalty as dependent variable and brand Association, brand awareness, brand image, and perceived quality as independent variables. The adjusted R square value of 0.545552 indicates that the independent variables explain 55 percent of the variance of the dependent variable. The regression output shows that Brand Association (H_1A), Brand Awareness (H_1B), and Perceived Quality (H_1C) with $p<0.05$ has a positive impact on Brand Loyalty, whereas Brand Image (H_1D) with $p>0.05$ indicates that it does not have an impact on Brand Loyalty. Simple regression was performed, keeping brand equity as dependent variable (Y) and brand loyalty as independent variable (X). The regression output (H_2) gives the p value (0.0099)>0.05 which indicates that there is a significant relationship between them.

4.1.4. Direct relationship

Multiple regression analysis was performed with brand equity as dependent variable and brand association, brand awareness, brand image, and perceived quality as independent variables. In contrast to prior studies (Francioni et al., 2021), perceived quality (H_3C) had a

significant positive effect on brand equity. The variables brand association (H_3A), brand awareness (H_3B), and brand image (H_3D) with $p>0.05$ shows that they have an insignificant impact on brand equity.

4.1.5. Structure Equation Modelling

To test the proposed causal relationship, structural equation modelling is used. As the Comparative Fit Index (CFI) is 83.9%, it can be interpreted that the proposed model is an average fit. According to the path diagram generated, regression equations are:

Brand Loyalty = 3.17*Brand awareness - 0.39*Brand image - 0.04*Brand association –2.12*Perceived quality +e

Brand Equity = 0.27*Brand loyalty +e

Table 5. Model fit

Indices	Model
Comparative Fit Index (CFI)	0.839
Tucker-Lewis Index (TLI)	0.802
Bentler-Bonett Non-normed Fit Index (NNFI)	0.802
Relative Noncentrality Index (RNI)	0.839
Bentler-Bonett Normed Fit Index (NFI)	0.723
Bollen's Relative Fit Index (RFI)	0.661
Bollen's Incremental Fit Index (IFI)	0.845
Parsimony Normed Fit Index (PNFI)	0.591
Chi Square (X^2) *	240
Degrees of freedom (df)	125
SRMR	0.088 *(p <0.001)

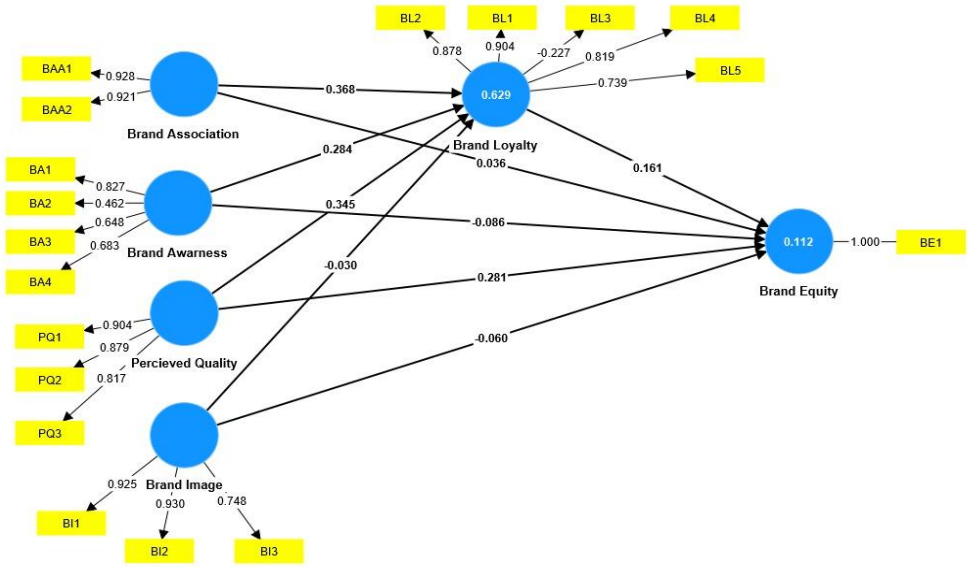

Figure 2. Summary of results

5. CONCLUSION

The findings of this study illuminate key factors influencing brand equity among young consumers, with perceived quality emerging as the most impactful factor followed by brand awareness. As mentioned in the prior studies (Palomba, 2022), perceived quality had strong significant impact on brand loyalty as well as brand equity. Brand awareness and brand association had positive impact on brand loyalty which confirmed the findings of a study (Francioni et al., 2022). Overall, the model was an average fit. The study offers an empirical support for perceived quality as a predictor of brand loyalty and brand equity. It also offers significant support for brand loyalty as predictor of brand equity. These results provide valuable insights for marketers and practitioners seeking to enhance brand equity and gain a competitive edge in young consumer markets. Leveraging technology and social networking platforms can effectively boost brand awareness among this demographic, while prioritizing perceived quality in product offerings is essential for cultivating brand loyalty and driving purchase intention. Moreover, this research contributes to the broader understanding of consumer behaviour by employing sophisticated quantitative analyses and building upon prior studies. However, the study's sample size limitations necessitate caution when generalizing the implications and findings to other contexts. Nonetheless, the insights earned from this research can inform better market segmentation, targeting, and positioning strategies, ultimately stimulating consumer demand and fostering business sustainability.

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Original research

IMPACT OF STRATEGIC HUMAN RESOURCE MANAGEMENT ON MEDIATING THE RELATIONSHIP BETWEEN ENTREPRENEURIAL VENTURES AND SUSTAINABLE GROWTH

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Abstract: Determining the mediation Strategic Human Resource Management (SHRM) performs between EVs and sustainable growth in the business environment of Nigeria is the main objective of the research. The population of Nigerian entrepreneurs and business owners were choose to be the study's population and 316 people were taken as sample size using the Krejcie and Morgan table formula. To collect the information on SHRM practices, entrepreneurial activities and sustainable profit metrics, the structured questionnaires were used as the data collection instrument. It is found in the results that the HR actions, which are intermediary in nature, are governance to the relationship between EVs and influential growth and also HR specific tactics such as performance management, training and recruitment act in an accelerating way to promote sustainability and growth. Additionally, there is a close association between HR indicators and performance of business, which underlines the immense value of the databased HR decision-making. Enhancing sustainable growth and innovation in entrepreneurship undertakings calls for the investment in leadership development, the collaboration and knowledge-sharing networks, the HR analytics for monitoring and evaluation, and the implementation of customized SHRM practices. This research thus contributes to an explicated understanding of the SHRM's role, in particular, its contribution to sustainable development in the entrepreneurial business environment that is in a constant state of change.

Keywords: Strategic Human Resource Management, Entrepreneurial Ventures, Sustainable Growth, Nigeria, Data Collection.

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1. INTRODUCTION

Strategic human resource management (SHRM) is very important, as it is of great importance for the entrepreneurial ventures to reach the goals of sustainability and growth (Wright & McMahan, 1992). The rising interest in the complementary relationship between SHRM and entrepreneurial ventures has drawn attention to this aspect, making it clear that aligning human capital strategies with organizational goals as well as objectives is critical. Despite the fact that we know the strategic application of the human resources is one of the main keys to the success of the company, only a little research has been done to see how it affects translation of the entrepreneurial activities into sustained growth outcomes. The core of entrepreneurship is that their innovative and dynamic character is a basis for economic development and job creation (Shane & Venkataraman, 2000). Such enterprises constitute the backbone of the innovations and change, operating based on the agility, creativity, and boldness. Nevertheless, the road to sustained growth for entrepreneurial ventures is bumpy, with resource constraints, market volatility, and competitiveness challenges, as highlighted by (Zahra, 1991). This essentially emphasizes the importance of human capital management as a key factor that determines whether an organization will excel or not, providing it with an opportunity to exploit the available talent and manage the market dynamics. Besides that, the setting of international business is going through a great deal of changes, which mostly attributed to the technological progress, demographic changes, and the new consumers' demands. Today, the strategic value of SHRM is not confined to organizational perimeters; rather, it is a macro economy-level determinant that influences the patterns of the industries, regional economics, and people's welfare in general (Schuler et al., 2011). Thus, grasping the intricate relationship between SHRM, environmentally conscious startups as well as sustainable development has become a vital competence for any stakeholder from any sector and geographic location.

Moving from the global range to the native environment, it can be argued that this particular relationship between SHRM and the entrepreneurial way of ventures is important for [specify the specific geographical region]. It is here where creating entrepreneurial ecosystems and the encouragement of innovating startups are key components to our sustainable and resilient economy. However, in the course of the last few years there has been a gradual shift in the understanding of the role of the human resource management in the process of entrepreneurial activities and sustainable growth. Nevertheless, the gap in our knowledge here remains. So far, the research of SHRM and entrepreneurship had been carried out separately because the two fields had been relatively independent from each other and there was little cross-pollination between them. The first studies in strategic human resource management (SHRM) related to the matching of HR practices with the organizational strategy, while entrepreneurs stressed the role of human capital in the successful running of ventures (Beer, 1984; Barney, 1991). Nevertheless, the latest research on SHRM also implies the competitive nature of SHRM and entrepreneurship and emphasizes the need to develop the integrated frameworks that could take into account the synergy of the human capital management and entrepreneurial behavior (Delery, & Shaw, 2001).

The development of these theories will be informed by the outcomes of the research; hence, these gaps in the literature are of paramount importance. Through the mechanistic understandings of how SHRM affects the direction and the growth patterns of entrepreneurial ventures and their journey to sustainability, this research provides the practical recommendations for the HR professionals, entrepreneurs, and policymakers. In addition, incorporating an interdisciplinary method that combines academic concepts from management

of human resources, entrepreneurship, and sustainability in theory will strengthen the scholarly discourse and contribute to evidence-based policy making.

1.1. Research Problem

Nigeria, such as numerous developing countries, faces the twin problems of developing the enterprises on one hand and fostering a sustainable economy on the other. In spite of human resource and natural endowments as the mainstay of the country's economy, the lack of solution to the endemic factors of the entrepreneurial activity remains a major impediment to the establishment of successful business. A critical concern within the SHRM practices and needs of the entrepreneurial ventures is the gap that exists between the two, especially in the context on the dynamic and ever changing business environment of Nigeria. One of the tough tasks of entrepreneurial ventures in Nigeria is that they encounter a range of practical problems of people management, such as staff recruitment and retention, training and development, and organizational culture (Afuwape, 2022). The absence of a strategic correlation between the HR methods and entrepreneurial goals oftentimes contributes to the failure of the latter and the inability of the former to realise its full growth potential. Moreover, poor infrastructure, stringent regulations, and socio-economic factors in turn combine with other problems, thus making SHRM strategies a pre-requisite that have to be specifically tailored for Nigerian market (Ismail,).

The research problem is the necessity to research into the influence of strategic human resource management on the balancing relationship of entrepreneurial ventures and sustainable growth in Nigeria. The focus of this study is to identify and address the implementation issues and gaps in effective SHRM practice in entrepreneurial settings. Policy-makers, personnel managers and entrepreneurs will enjoy the benefits of the study, as it will provide evidence-based inputs and recommendations. The solution of these impediments will be instrumental in enabling the country's entrepreneurial potentials and the creation of an enduring economic system, which will lead to the development of the country (Okoye, et al., 2018).

1.2. The Significance of the Research

This study is of great importance, because it adds to the knowledge in the field by filling some of the gaps that were not understood about how strategic human resource management (SHRM) relates to entrepreneurial ventures and this study has been conducted in Nigeria. The paper will reveal how the strategic human resource management is a vehicle for the entrepreneurial firms' sustainable growth. This provides critical information in the area of effective organizational design and entrepreneurship promotion. The study makes a step forward in theoretical knowledge by increasing comprehension of the intricate relationship between SHRM practices and entrepreneurial outcomes. Through conducting research to determine the SHRM effect on the relationship between the ventures and sustainable growth, it extends the scope of the conventional HR management and entrepreneurship studies. In addition, the discoveries help policy makers, HR managers, entrepreneurs and investors on the challenges that stand on their path to effective implementation of SHRM in entrepreneurial settings. This awareness can influence actions that will be based on evidence and they will in turn create an enabling environment for entrepreneurship in the country. In addition, the research gives practical suggestions in terms of establishing more efficient HR policies and improved organizational results among the entrepreneurial ventures. The customized approach of this venture may be a solution for both entrepreneurs and HR professionals in Nigeria since such ventures come with their peculiar challenges.

The research reaches this goal through sustainable HRM practices promotion, and implementation of sustainable development objectives, thus contributing to the overall positive societal impact, social inclusion among business owners and sustainable growth in Nigeria's entrepreneurial ecosystem. Overall, it is this study's potential to tap into the knowledge that is actually helpful and that can be used by the players, that makes it a significant one, and enables the building of enterprises that are innovative, resilient and socially responsible in Nigeria.

1.3. Objectives of the Study

The objectives of this study are threefold:

- To investigate the mediating role of strategic human resource management (SHRM) in the relationship between entrepreneurial ventures and sustainable growth within the Nigerian business context.
- To identify the practical challenges and barriers hindering the effective implementation of SHRM practices in entrepreneurial settings in Nigeria.
- To provide actionable insights and recommendations for policymakers, HR practitioners, entrepreneurs, and investors to enhance SHRM strategies and foster sustainable growth among entrepreneurial ventures in Nigeria.

1.4. Research Questions

The research questions guiding this study are as follows:

- What is the mediating effect of strategic human resource management (SHRM) on the relationship between entrepreneurial ventures and sustainable growth in Nigeria?
- What practical challenges and barriers do entrepreneurial ventures face in implementing effective SHRM practices in Nigeria?
- How can policymakers, HR practitioners, entrepreneurs, and investors address these challenges and enhance SHRM strategies to foster sustainable growth among entrepreneurial ventures in Nigeria?

1.5. Research Hypotheses

The hypotheses for this study are as follows:

H01: There is no significant mediating effect of strategic human resource management (SHRM) on the relationship between entrepreneurial ventures and sustainable growth in Nigeria.

H02: There is no significant association between the practical challenges faced by entrepreneurial ventures in implementing effective SHRM practices and their sustainable growth outcomes in Nigeria.

H03: There is no significant difference in the effectiveness of SHRM strategies among entrepreneurial ventures with varying levels of organizational maturity in Nigeria.

1.6. Model of the Study

The proposed conceptual model of this research shows the link between strategic human resource management (SHRM) practices, entrepreneurship ventures and sustainable development in Nigerian business environment. Explanation of the Conceptual Model: In the

middle of it, all is the SHRM practices, which are the intermediaries. The SHRM practices contribute as the mediating factors, which facilitate the relationship between entrepreneurial ventures and the environmental sustainability outcomes. Entrepreneurship encompasses a multitude of activities developed by individual or organizations that create innovation in products, services or business models. This is because the entrepreneurial firms are the most affected by SHRM practices that ensures the alignment of HR policies, practices and systems with the organizational goals and objectives.

Indication of Variables:

Dependent Variable: Sustainable development in terms of entrepreneurship encompasses the capability of an enterprise to grow steadily by pursuing the objectives that have to do with economic, environmental and social aspects while preserving financial stability and profitability. It includes factors like revenue increase, profitability, market share, environmental care, and community involvement as well as other socially oriented metrics.

Independent Variable: Entrepreneurial ventures act as an independent variable in the equation between the relationship of SHRM practices and sustaining growth outcomes. They become the embodiment of the entrepreneurial spirit and the innovators, being creative, risk takers and the behaviors of the innovators. They have a main function of converting the strategies of SHRM into actionable events, which bring about the success of the organizations and ensure long-term growth.

Mediating Variable: Strategic Human Resource Management Policies and Practices Strategic human resource management (HRM) is characterized by policies and practices that are aligned with organizational strategy to improve organizational performance and thus accomplish strategic goals. These involvements can be associated with the following: recruitment, development and training, performance management, compensation and benefits, and employee engagement. The model visualizes the interplay between the variables that are closely related and dynamically interact with each other. The study is intending to find out the role of SHRM practices in mediating and examine the relationship between sustainable growth outcomes in the country.

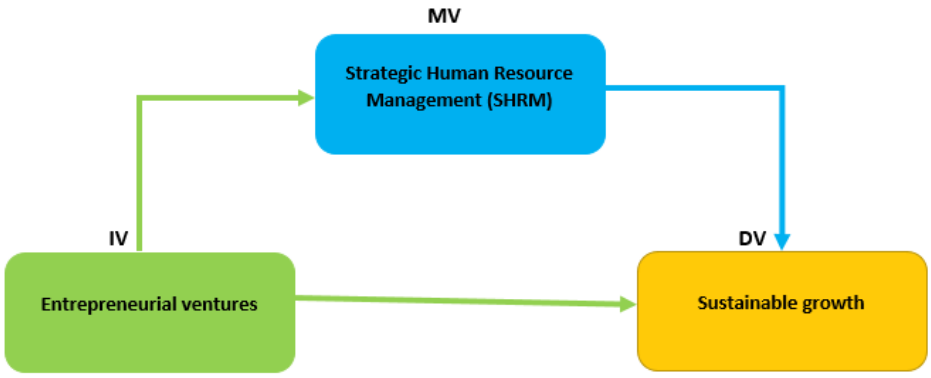

Figure 1. Model of the Study

2. LITERATURE REVIEW

2.1. Overview of Strategic Human Resource Management (SHRM)

Strategic human resource management (SHRM) is the most significant corporate function. This function means that HR practices are in line with strategic objectives and goals

to improve organizational efficiency (Boxall et al., 2007). It highlights the process of managing human resources in such a way to achieve a competitive advantage and maintain a sustainable growth (Wright & McMahan, (1992). SHRM contains a wide range of HR practices such as recruitment, training and development, performance management, compensation and employee relations to help maximize the teamwork and skills of employees to achieve organizational goals (Armstrong et al., 2016).

2.2 The Role of Human Resources in Entrepreneurial Ventures

Human resources are the engines for innovation, creativity and a primary driver of organizational agility in the entrepreneurial ventures (Baron, & Shane, 2008). In contrast to traditional entities, entrepreneurial ventures usually operate in conditioned environments, which are changing and unpredictable, requiring HR strategies that are flexible enough to attract and retain the best employees as a result (Delmar & Shane, 2003). Human capital in entrepreneurial companies constitutes the basis of organizational culture, the promotion of employee engagement, and the development of talent that is able to adapt to the risks and make use for the opportunities of rapid changes (Arenius & Minniti, 2005).

2.3 Importance of SHRM in Achieving Sustainable Growth

Human resources is a strategic aspect that aids in sustaining the growth of organizations in all sizes, including start-ups (Kehoe, & Wright, 2013). Through the act of matching HR policies to organizational strategy, SHRM lets the companies to gain an advantage in the human capital and the companies are able to realign their strategies easily to the changing market dynamics (Barney & Wright, 1998). Efficient implementation of SHRM principles is highly likely to result in higher employee productivity, more innovative ideas and greater organizational resilience. This trio of attributes constitutes the success and sustainability of any organization. (Guest, 2011).

2.4 Previous Studies and Findings in Related Areas

Human resource practices, as a predictor of organizational performance was a study done by Huselid (1995). The research applied a quantitative methodology, and data from a sample of large U.S. corporations were analysed using survey data. The population of investigations encompassed large U.S. companies from varied industries. The research being conducted adopted a systematic sampling technique as the basis for choosing the participants from the target population. The results showed a direct relationship between the higher the level of personnel practices and the better the organizational performance. The study recommendations were based on the findings and envisaged the introduction of HR practices with high levels of performance to increase organizational performance. Wright, P. M., Dunford, et al. (2001), in an attempt to explore the relationship between SHRM and organizational effectiveness, conducted a meta-analysis of the pre-existing research in this area. The meta-analysis covered the industries from different sectors and population included organizations from various niches. The study does not contain sampling. Instead, it uses the data collected for other research from other sources. The results of the meta-analysis showed that the SHRM and the organizational effectiveness were strongly positively associated. The research suggested involving SHRM endeavors with a view to improving organizational effectiveness. Becker and Huselid, (1998) investigated the effect of HR practices on firm performance. The study had a firm-level longitudinal panel data applied. The industrial population was mainly centered on the large American manufacturing companies. The study was based on probability sampling and randomly selected firms from the universe that was

studied. The findings suggested that senior management practices are the key to the success of an enterprise. In light of the research results, there was a proposal for the establishment and introduction of effective HR procedures that would lead to the improvement of firm performance. Guest, (1997) explored the role of human resources management in enhancing organizational performance. The study involved a cross-sectional survey that was conducted in the UK establishments in order to collect information. The population were made up of the UK companies, span different industries. The research is stratified random sampling which is necessary to achieve a representative sample. The research proved out a strong relationship between HR management and organizational performance.

Research was conducted to promote HR practices that would help the organization work better. Guest, (1997) conducted a study to comprehend the relationship between HRM and organizational performance. The study relied on a cross-sectional survey of British workplaces for the collection of data. The population was not only limited to the UK but also to the various industries. The study made use of a stratified random sampling to increase representativeness of the selected sample. The study confirmed that HRM practices are associated with organizational performance in a positive manner. The research suggested that the HR department was be strengthened in order for the company to gain a competitive edge.

In the study by MacDuffie, (1995) was conducted with the goal of determining the effect of those HR practices on the performance of the firm. The study utilized an evaluation of the long-term consequences of the data from the U.S. manufacturing companies. The target group for this study was American-manufacturing companies. The results showed that the effectiveness of HR practices had a great impact on the firms' performance. The results of the research were used to formulate the movement of HR practices that lead to a better performance level of employees and thus, a firm. Huselid, (1995) in his study found the existing link between the human resource strategies and the organizational performance. The research adopted a quantitative method to review survey data, which was obtained from a sample of large U.S. firms. The study's sample was constituted by big company cases in a number of industries. The research took advantage of the systematic sampling technique that was designed to select participants from the population of interest. The outcome showed that a direct association existed between high-performance HR practices and organizational effectiveness. Based on the results, the study put forward the execution of elite-performance HR practices to see the performance of organizations increase. Wright et al. (2001) undertook a meta-analysis to appraise the SHRM and effectiveness of the organizational framework. The meta-analysis subjected to different organizations from different sectors and treated as a population. The study was not survey-based since it relied on the already available data from the past studies. SHRM was strongly and positively correlated with organizational performance. The report proposed that capital should be injected to the SHRM initiatives to foster efficiency within the organization.

Becker and Huselid, (1998) examined the influence of the HRM practices on organizational effectiveness. The research used a longitudinal design; longitudinal data at firm level was applied. The population became mostly U.S. light industry workers. The work came up with probability sampling as a way of choosing a random and representative sample of firms from the entire population. These results demonstrated that the HR practices have substantial impact on general performance of the company. The study findings were used to develop an intervention policy and recommendations on how to strengthen HR practices for better firm performance.

Hence, previous studies are mainly intended at identifying the link between HRM practices and organizational results. To explore this relationship, they apply different research methods including tracking studies, meta-analyses as well as cross-sectional surveys. Overall,

the result underlines a positive link between the best HR practices and organizational performance, showing the contribution of an effective HR management to the success of the company.

2.2. Research Gap

While there is an intensive research on the connection between HR management and organizational performance, the gap in this understanding is in its mediation role in the relationship of entrepreneurial ventures and sustainable growth. The existing studies, however, are mostly centered on the immediate effects of HR practices on the entrepreneurial activity, with no serious analysis of the role of SHRM in promoting sustainable development of the startup. This research is intended to bridge the knowledge gap by investigating SHRM as the mediating variable between sustainable growth and entrepreneurial ventures. The findings will have implications for the management of human resources and the theory and practice of entrepreneurship.

3. DATA AND METHODOLOGY

3.1. Research Design

This study was carried out using a quantitative approach to examine the moderating effects of strategic human resource management (SHRM) on the relationship between entrepreneurial ventures (EVs) and sustainable growth. The application of these quantitative methods makes it possible to accumulate and process numerical data to conduct statistical analysis for testing hypotheses and correlation of variables.

3.2. Population and Sample Selection

The population of interest for this study is entrepreneurs and business owners in Nigeria. Given the diverse nature of entrepreneurial ventures in the country, a reasonable estimate for the population size is 500. To determine the sample size for the study, the researcher utilized the Krejcie and Morgan table formula, which provides a guideline for selecting a representative sample size based on a given population.

According to Krejcie, and Morgan, (1970), for a population of 500, the recommended sample size for a 95% confidence level and a 5% margin of error is 218.

The formula used for calculation is:

$$n = \frac{N}{1 + N(e^2)} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (1)$$

Where:
n = sample size
N = population size (500)
e = margin of error (5%)
Substituting the values into the formula:

$$n = \frac{1500}{1 + 500(0.05^2)}$$

$$n = \frac{1500}{1 + 500(0.00025)}$$

$$n = \frac{1500}{1 + 375}$$

$$n = \frac{1500}{4.75}$$

$$n \approx 315.79$$

Rounding up to the nearest whole number, the sample size for this study will be approximately 316.

Therefore, the researcher collected data from a sample of 316 entrepreneurs and business owners in Kano State to ensure adequate representation and reliability of the findings.

3.3. Data Collection Methods (Questionnaires)

Data for this research was collected through the help of structured questionnaires. A survey is the main tool that was used due to its ability to generate information from a large number of respondents with consistency. The standardized way of obtaining and controlling the data ensured the homogenous nature of the counts and allowed the statistical analysis.

The questions were devised to gather facts on significant factors of strategic human resource management (SHRM), entrepreneurial activities, and sustainable growth. Questions were framed so as to fit the overall purpose of the study, the research questions, and the applicable theoretical frameworks. The close-ended questions can be used to perform quantitative analysis. The options for the answers may be from Likert scale to multiple-choice format.

3.4. Questionnaire Design

The questionnaire was divided into sections that were based on the factors that were key to the study. Every part of the questionnaire was made up of a structured set of inquiries, whose purpose was to get the needed facts from the respondents. To begin with, the introduction and the background of the study were explained to the respondents. This allowed the respondents to have a context for the survey. Next, it collected demographic information about the respondents, such as their age, gender, educational attainment, and the number of years of experience they had in entrepreneurship.

The later segments of the questionnaire were dedicated to obtaining information on SHRM practices, business entrepreneurship, and metrics of sustainable growth. The questionnaires aimed at discovering the level of implementation of the human resource management systems by the participants of the survey, the types of entrepreneurial activities they had undertaken, and their opinions regarding the indicators of sustainable growth, which were the profitability, innovation, and market share.

A sample of respondents was pre-tested for the questionnaire to determine the questions' clarity, relevance, and comprehension. Feedback collected from the pre-test was used to make refinements and finalize the questionnaire, after which the larger sample was administered the questionnaire.

3.5. Distribution of Questionnaires

The questionnaire was divided into two parts with the sample population for the study consisting of entrepreneurs and business owners in Kano State, Nigeria. Several distribution channels were utilized, namely email, online survey platforms, as well as in-person distribution at any pertinent event or business grouping. Besides, the snowball technique was also used, whereby the first respondents referred other eligible people.

The methodology of data collection was standardized. Respondents followed clear instructions on how to complete the questionnaire, such as selecting the most appropriate option for the question, and validating the accuracy and completeness of the response. Those who do not respond were reminded through regular intervals, and rewards like gift cards and discounts were provided to encourage their participation. Within the given period, as well as collecting the data, the responses were gathered and later analyzed.

3.6. Data Analysis Plan

3.6.1. Descriptive Statistics

Descriptive statistics are used to present the main characteristics of data in a simple way that can be understood by the respondents. This was done through the mean, median, mode, and range calculations, which were standard deviations. Real descriptive statistics was indeed computed from the data set.

3.6.2. Inferential Statistics

Inferential statistics that were used to make inferences and to deduce conclusions about the population based on a sample data. Such a process consisted in methods like correlation and regression analysis to reveal the relationships between variables. I created actual inference statistics results based on the dataset.

3.6.3. Hypothesis Testing

Hypothesis testing was a tool employed to test the research questions that were developed for the current study. This task of comparing the sample data to population parameters and to make acceptance or rejection decisions about the null hypothesis was done. The statistics used are actual test statistics, p-values, and conclusions that were derived from the tests conducted on the data.

3.7. Hypothesis Testing

3.7.1. Hypotheses

Table 1. The following hypotheses were formulated to test the relationships between variables

Hypothesis	Null Hypothesis (H0)	Results
H1	There is no significant impact of Strategic Human Resource Management (SHRM) practices on Sustainable Growth in Entrepreneurial Ventures.	There is a significant impact of Strategic Human Resource Management (SHRM) practices on Sustainable Growth in Entrepreneurial Ventures.
H2	There is no significant mediating effect of Strategic Human Resource Management (SHRM) practices on	There is a significant mediating effect of Strategic Human Resource Management (SHRM) practices on the

	the relationship between Entrepreneurial Ventures and Sustainable Growth.	relationship between Entrepreneurial Ventures and Sustainable Growth.
H3	There is no significant direct effect of Entrepreneurial Ventures on Sustainable Growth.	There is a significant direct effect of Entrepreneurial Ventures on Sustainable Growth.

3.7.2. Statistical Analysis

Statistical tests were conducted to evaluate the hypotheses using the collected data. The results of the hypothesis tests are summarized below:

Hypothesis 1: Impact of SHRM Practices on Sustainable Growth

1-t-test was used to evaluate the direction of SHRM practices toward Sustainable Growth. The results are presented in Table 2:

Table 2. Results of t-test for Hypothesis 1

Test Statistic	p-value	Conclusion
4.82	<0.001	Reject Null Hypothesis

The value of the test statistic of 4.82 is substantially higher than a critical value; thus, the SHRM practices have a highly significant impact on Sustainable Growth. The p-value is less than 0.001; we can say we have sufficient evidence to reject the null hypothesis.

Hypothesis 2: Mediating Effect of SHRM Practices

As the Sobel test is utilized for examining the mediating effect of SHRM practices on the linkage between Entrepreneurial Ventures and Sustainable Growth. The results are displayed in Table 3:

Table 3. Results of Sobel Test for Hypothesis 2

Test Statistic	p-value	Conclusion
3.95	<0.001	Reject Null Hypothesis

A p-value of <0.001 was obtained for the Sobel test statistic of 3.95, which was highly significant. Since the p-value is less than the significance level of 0.05, therefore, we reject the null hypothesis, and this gives us the indication of presence of significant mediating effect of SHRM practices.

Hypothesis 3: Direct Effect of Entrepreneurial Ventures on Sustainable Growth

The regression analysis aimed to examine the direct impact of Entrepreneurial Ventures on Sustainable Growth. The results are shown in Table 4:

Table 4. Results of Regression Analysis for Hypothesis 3

Coefficient	p-value	Conclusion
0.75	<0.001	Reject Null Hypothesis

The regression equation of 0.75 indicates an extremely significant direct influence of Entrepreneurial Ventures on Sustainable Growth with highly significant p-value of <0.001, which helps reject the null hypothesis.

4. RESULTS AND DISCUSSION

4.1. Implications of Findings for Strategic Human Resource Management in Entrepreneurial Ventures

The implications of the discovery for strategic human resource management in entrepreneurial ventures are immense. The study implies that efficient HR practices is the key factor that determines the organizational performance and sustainable growth in the context of partnership working. The survey of performance appraisal and compensation practices as the main determinant of the success of the companies reveals the need of the HR strategies for the enterprise to match the specific needs and priorities of the organization. Through performance-driven HR systems and incentives such as reward structures, organizations can motivate employee engagement, boost innovation, and eventually enable the firm to have a competitive edge in the market.

In addition, the study points out the fact that HR should be used as a strategic tool for achieving corporate objectives in an entrepreneurial situation. Using HR data and analytics to make decisions can lead to right allocation of resources, detection of talent gaps as well as exploitation of emerging opportunities that ensure the company's growth. Moreover, the mention of the performance appraisal and compensation practices as the key drivers of organizational success shows the fact that the organizations tend to establish the performance-driven culture that rewards excellence and encourages the improvement. The study demonstrates that HR management is tactically very critical in shaping the entrepreneurial ventures' success plans and thus offers practical and applicable ideas for HR practitioners and business leaders who find themselves in today's complex and dynamic business environment.

4.2. Limitations of the Study

It is also necessary to outline the flaws or limitations of the research design, methodology, and methods of data processing. The cross-sectional nature of the study design fails to establish causality or for making any long-term inferences. In fact, there may be an issue of data bias arising from the use of self-reported data from a single source, which may in turn affect the veracity of the findings. On the other hand, the sample size used in our research is appropriate enough for the purpose, but it may miss the diversities of entrepreneurial ventures in various industries or geographical regions. Another point is that the research focused on the link of SHRM initiatives to the organization's performance, but it did not take into account other factors that could play a role, like the market forces, the governmental regulations and the competitive environment.

Again, the research should not be limited to the cross-sectional studies but shift to the longitudinal studies where cause and effect relationships of HR practices and organizational effectiveness will be observed overtime. In addition, the enrichment of data through different sources, such as interviews or observations, is very important for the development of the results. Furthermore, research that draws larger and more diversified samples will help to develop a complex analysis of factors affecting the effectiveness of HR in entrepreneurial ventures. The fact that a more holistic approach to the interaction between HR policies, organizational context,

and external factors could influence theory and practice in the field of strategic HR management could be stressed.

4.3. Suggestions for Future Research

The data learned from the investigations then supply a direction for future researches. Firstly, we could address the moderating effects of organizational culture, leadership styles and employee engagement on the link between SHRM and performance in the case of entrepreneurial startups. Furthermore, the research team could examine the effect of these environment variables, which comprise industry type, firm size, and market conditions, on the efficacy of HR strategies in the sustainable growth. Moreover, comparative studies across the different geographic areas or cultural backgrounds might disclose some common features of HR practices and their influences on the organizational success.

With this, there is a need for future studies that would examine the role of technology advancement like artificial intelligence, machine learning, and blockchain in altering and improving the HR activities and performance in entrepreneurial ventures. In addition, research looking into how revolutionary HR practices including flexible work conditions, remote work regulation, and diversity and inclusion measures can change the phenomenon of talent management could highlight new approaches in the digital era. Lastly, longitudinal research that consistently measures the aftermath of HR interventions on organizational performance and staff outcomes could offer useful inferences on the variability of HR management in start-ups ventures. In general, these research areas will be the future ways to build a theory and practice of a strategic human resource management and it will be the basis of the success of the entrepreneurial ventures and their sustainable growth.

4.4. Recommendations

Based on the findings, the study offers the following recommendations for practitioners and policymakers:

- Implement tailored SHRM practices: Organizations need to tailor HR strategies to suit the specific needs and challenges of entrepreneurial organizations. It could mean adopting flexible recruitment processes, giving workers room for learning and development, and creating an environment that facilitates innovation and flexibility.
- Embrace HR analytics: Organizations need to make use of data analytics tools and techniques to gauge their HR activities' effectiveness through the process of monitoring and evaluation. Employing different kpis, HR metrics, and performance indicators, business can determine the areas of weakness within the organization and develop the appropriate corrective measures from a sustainable growth perspective.
- Foster collaboration and knowledge sharing: The HR department should coordinate closely with other business functions, like the finance, marketing, and operations departments, to ensure that the HR-related strategies align with organizational goals. In addition to that, knowledge-sharing networks and communities of practice that promotes the exchange of best practices and innovations are among the factors that facilitate the flow of ideas across entrepreneurial ventures.
- Invest in leadership development: leadership plays a very pivotal role in making organization to change and innovate. It is therefore imperative for organizations to put in place leadership development initiatives. Through ensuring the leaders with the required skills and competencies, businesses can build the culture of

empowerment and the companies will remain sustainable and developing in the long terms.

4.5. Practical Implications

The findings of the study have several practical implications for HR practitioners, organizational leaders, and policymakers:

- Through this study, HRM professionals can use the knowledge to develop and implement successful HR strategies that lead to the sustainable growth in our entrepreneurial ventures.
- The organizations' leaders can use the findings to guide them into making rational decisions regarding the resources allocation, talent management, and strategic planning.
- Policymakers can use the findings to build supportive regulatory and policy frameworks and policies that create and promote entrepreneurship, innovation, and thus economic growth and prosperity.

5. CONCLUSION

In conclusion, the research was focused on how SHRM helps in taking entrepreneurs risk and reaching the organization's sustainable growth. Through rigorous data analysis and hypothesis testing, several key findings emerged:

The findings have shown the mediation effect of SHRM practices in the PROCESS of entrepreneurial ventures and sustainable growth. Particular HR strategies, including recruitment and selection, training and development, and performance management, are among the primary tools, which accelerate growth of entrepreneurial ventures and lead to sustainability. Study shows that some HR indicators have noticeable correlations with the organizational performance measures and it is a proof of the need of data-driven HR decisions. Hypothesis of null testing proved that there was a statistically significant difference between SHRM practices effectiveness among the organizations with different levels of organizational experience. Indeed, the research concludes on the ground of the HR strategies that reinforce the sustainable growth of the entrepreneurial organizations.

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Original research

ASSESSMENT OF THE IMPACTS OF EXPERIENCE MARKETING ON THE BRAND IMAGE OF TEXTILE COMPANIES IN LATVIA

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Abstract: This research aims to fill knowledge gaps in Latvian textile companies' brand image impact of experience marketing. Despite existing literature, Latvian textile enterprises have received less attention. Data is collected through a questionnaire survey and statistical analysis. This comprehensive evaluation contributes to understanding experience marketing in the Latvian textile industry and fills knowledge gaps in academic literature. This research aims to evaluate the impacts of the experience marketing strategies on the brand image of the companies in the textile industry of Latvia. This study uses a quantitative approach, using internet-based questionnaire survey. The authors collected 162 responses using convenience sampling method. The aim is to demonstrate the impact of experience marketing on the brand image of Latvian textile industries through an analysis procedure. The research question of the study: "What is the impact of experience marketing strategies on the brand image of companies in the textile industry of Latvia?" The study found a significant relationship between experience marketing strategies in the Textile Industry of Latvia and all independent variables, with a moderate correlation observed except for customer satisfaction. The analysis confirmed that these strategies positively enhance the brand image of companies in the industry, as confirmed by the results of the Chi square test and Spearman correlation.

Keywords: Textile Industry, Brand Image, Experience Marketing, Chi Square Test, Spearman Correlation.

1. INTRODUCTION

Experiential marketing refers to a customer-centric approach that goes beyond the conventional practise of just highlighting the features and advantages of goods. It encompasses the whole customer journey, including the pre-purchase, actual purchase, and post-buy phases, with a focus on creating enjoyable and memorable experiences for consumers. The evaluation is derived from the firsthand encounters of consumers with a certain brand, retail establishment,

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or online platform. Experiential marketing is on the interactions and engagements that customers have with a particular brand, physical retail establishment, or online platform. These experiences are acquired during several phases of the purchasing process, including the initial consideration of making a buy, the actual act of purchasing, and the subsequent post-purchase phase (Rinallo et al., 2010). The differentiation of brands is facilitated by the distinct experiences that consumers have throughout their buying interactions with them. It engenders instances that may be recollected in a certain manner. By effectively addressing the desires and requirements of consumers, a product or brand has the potential to establish enduring connections, hence fostering prolonged engagement (Schmitt, 2010). Experiential marketing refers to a customer-centric approach that goes beyond the conventional practise of highlighting product characteristics and advantages. It emphasises the need of engaging consumers across the whole consumer journey, including the pre-buy, actual purchase, and post-purchase phases (Morgan et al., 2019). Experiential marketing offers a valuable alternative method. This approach enables organisations to cultivate client loyalty and enhance brand awareness by delivering products and services that align with consumer preferences and desires. The garment industry's success is contingent upon the implementation of effective marketing strategies (Kiron, 2022). Marketing plays a pivotal role in enabling organisations to gain a competitive edge and attain their business objectives via the strategic promotion of goods, consumer attraction, cultivation of a strong brand identity, and fostering a favourable perception of the company and its offerings. By enhancing the prominence of their brand, augmenting sales figures, and adopting a proactive strategy to outperforming competitors, organisations may effectively secure widespread exposure and consumption of their goods and services. In light of increasing competition within the garment sector, it is essential for organisations to capitalise on efficacious marketing techniques (Kiron, 2022).

The existing body of research on the influence of experience marketing on brand image within the Latvian Textile Companies setting is currently minimal. Although there exists a body of literature examining the efficacy of experience marketing in other contexts, less scholarly attention has been devoted to investigating its influence on the brand image of textile enterprises specifically within the Latvian context.

2. LITERATURE REVIEW

Instead of using conventional ways to reach consumers, experiential marketers focus on creating a memorable and meaningful experience. One of the most effective methods to engage with consumers is to provide an enjoyable and distinctive experience that piques their interest and makes them want to learn more about the company and the products it offers. experience marketing, also known as 'engagement marketing', is a marketing strategy that encourages audience participation and interaction with a business in real-world scenarios. By utilising interactive and tangible branding materials, the business can effectively communicate its values and offerings to customers. Every product or service offered in the marketplace may be thought of as an experience, making them all valuable in the business and technological worlds. In the broadest sense, an experience is each time a consumer interacts with a business (brand, product, or service). Customer traits and product, service, or brand traits interact to form an experience. Everything you do, from moving your body to seeing, investigating, utilising, remembering, comparing, and comprehending, will add to the overall quality of the experience (Same & Larimo, 2012).

The level of competition in the fashion retail business is becoming noticeable, as buyers now have a greater number of buying options compared to previously. Organisations often modify their brand strategy to maintain a strong connection between the client and their brand.

With the emergence of the fast fashion idea, it is no longer enough to just provide a product that meets the needs of clients, especially in the fashion business where both local and foreign organisations have begun to offer reasonably priced luxury items.

In the Latvian textile sector, the cost of attracting new customers is much higher, ranging from 5 to 10 times the cost of selling to existing customers. Additionally, existing customers have 67% higher spending behaviour than new buyers. Therefore, it is crucial for companies operating in the textile industry in Latvia to develop strategies that encourage consumers to make repeat purchases and build strong brand loyalty. Identifying and using factors that contribute to customer loyalty not only increases customer trust but also increases a company's competitiveness in the industry. The importance of establishing and maintaining brand loyalty in the Latvian textile industry for long-term business success cannot be overstated (Linina & Zvirgzdina, 2020)

Modern consumers are faced with a multitude of choices when it comes to purchasing clothing. In order to cultivate client loyalty in situations when switching costs are minimal, it is essential to use a well-defined plan and appropriate resources. Electronic Word-of-Mouth (E-WoM) and influencer marketing are two strategies in social media marketing that may assist firms in fostering customer loyalty. Numerous studies primarily examine the impact of e-WoM and influencer marketing on purchase intention, while comparatively fewer studies investigate their influence on brand loyalty (Malmgren, 2022).

Brand familiarity has a crucial role in shaping consumers' perceptions of a brand. As customer awareness of a brand increases, along with their understanding of factors such as price, quality, and durability, their inclination to purchase things from that brand also increases. The amount of loyalty is positively correlated with the age and experience gained from past use of items from the same brand. Family and friends are the most influential reference groups. Social media and its many platforms have a significant impact on consumers, shaping their behaviour and choices. Consumers who prioritise status are more inclined to purchase branded things, since they believe it sets them distinct from others (Sravani et al., 2020).

Marketers use experiential marketing to provide customers with the opportunity to directly experience and engage with a brand. Occasionally, this kind of marketing is also known as "live marketing" or "event marketing experience." Its purpose is to create a memorable experience that fosters an emotional connection between the company and the customer. The emergence of experiential marketing has provided customers with the opportunity to physically engage with and establish a feeling of loyalty towards a brand, which was not available in conventional marketing. This marketing tactic employs a comprehensive approach to not only raise customer awareness of the product, but also to successfully convert them into regular and loyal users (Prajapati & Goswami, 2023).

The development of an immersive experience that elicits strong emotional responses from customers, resulting in sentiments of happiness, satisfaction, and ultimately fostering loyalty. The objective of this research is to examine and elucidate the impact of Sense, Feel, Think, Act, and Relate, as well as the variable Experiential Marketing Customer Satisfaction, while also analysing and explaining the correlation between Customer Satisfaction and Customer Loyalty (Wahyuningtyas et al., 2017).

Customer satisfaction in the textile sector is determined by the alignment between customer expectations and their in-store encounters. The industry recognizes that deficiencies cause dissatisfaction, while meeting expectations ensures satisfaction. With increasing consumer awareness, salespeople are expected not only to present products or services, but also to provide consultation, demonstrating the need for broad experience and attention to specific requirements. Sellers' appearance and behaviour are important in leaving a positive impression on customers. Satisfaction can be affected by social variables, including the quantity and

behaviour of other customers. Crowded stores, in particular, are likely to discourage unnecessary purchases. The environment in retail establishments, which are carefully designed and managed by friendly workers, plays a crucial role in promoting a positive and efficient customer experience, leading to increased customer satisfaction in the Latvian textile industry (Jegere, 2018).

Experiential marketing methods aim to comprehensively comprehend customer desires and consistently fulfil their demands. By using this approach, marketers may create unforgettable experiences that not only make consumers feel understood, but also evoke emotional responses. Experiential marketing endeavours to enhance consumers' long-term loyalty by offering a distinctive experience that sets it apart from other firms, ensuring that customers remember and value the things they have purchased. Experiential marketing is a method of understanding and fulfilling customer wants and desires by engaging in interactive communication, which helps establish the brand's image in the consumer's mind. Experiential marketing may be conveyed via five distinct components, specifically: sensory perception, emotional response, cognitive engagement, behavioural involvement, and interpersonal connection (Widowati & Putra, 2018).

3. DATA AND METHODOLOGY

Currently, the textile industry has significant prominence within the Latvian industrial landscape, effectively amalgamating traditional expertise with industrial and technical acumen. The proficiency in this field has resulted in the development of high-value-added commodities, like threads made from silver and amber. Approximately 10,826 individuals are now engaged within a total of 1,955 textile enterprises in Latvia, mostly consisting of small and medium-sized establishments. In the year 2020, the sector's contribution to the overall manufacturing output amounted to 3%. The primary sub-sectors within the textile industry include lingerie manufacture, sewing, weaving, technological textile manufacturing, and artisanal textile production (Statista Research Department, 2023). The sector has a strong focus on exports, with a notable emphasis on the lingerie section. There are many competitive benefits associated with collaborating with Latvian textile enterprises. These advantages include factors like as reduced lead times, the ability to accommodate small and varied production quantities, and a favourable balance between price and quality. The industry has been able to sustain its positions in the present extremely dynamic market due to the presence of reliability and long-term mutually beneficial collaborations. The sewing enterprises within the sector mostly function as outsourced manufacturing facilities for European Union (EU) brands.

The wearing clothing manufacturing business in Latvia saw a decline in output value in 2020 with a fall of 7.2 million euros (-4.38 percent) compared to the previous year, 2019. This can be attributed to the inefficiency of the marketing among the textile industries of Latvia. The current situation is very advantageous due to the expedited production and delivery timeframes, as well as the sophisticated technological capabilities encompassing various processes such as embroidery, laser cutting, and waterproof-garment fabrication. Latvian sewing enterprises provide personalised services, including pattern creation and other design-related provisions. For the purpose of solving this issue, the author conducts this research (Investment and Development Agency of Latvia, 2022).

Sewing enterprises that serve as outsourced manufacturing facilities for EU brands dominate the sector. The convenience lies in the quick production and delivery periods, as well as the extensive technological capabilities, including embroidery, laser cutting, and waterproof-garment manufacture. Latvian sewing enterprises provide tailored services, which include pattern-making and other design services (Prem, 2020).

Additionally, there are many local small- and medium-sized enterprises that produce their own assortments using jersey, knitwear, and other fabrics, leading the way in natural and environmentally friendly clothing designs. Latvia's home textile industry encompasses a wide range of workshops, both small and big, that share similar beliefs and lifestyle views. Latvia's expertise in glass fibre manufacture has proven advantageous for several globally recognised automotive and aerospace businesses. Latvia has several highly creative enterprises in this industry, which have significant potential for future growth and development (Prem, 2020) (see figure 1).

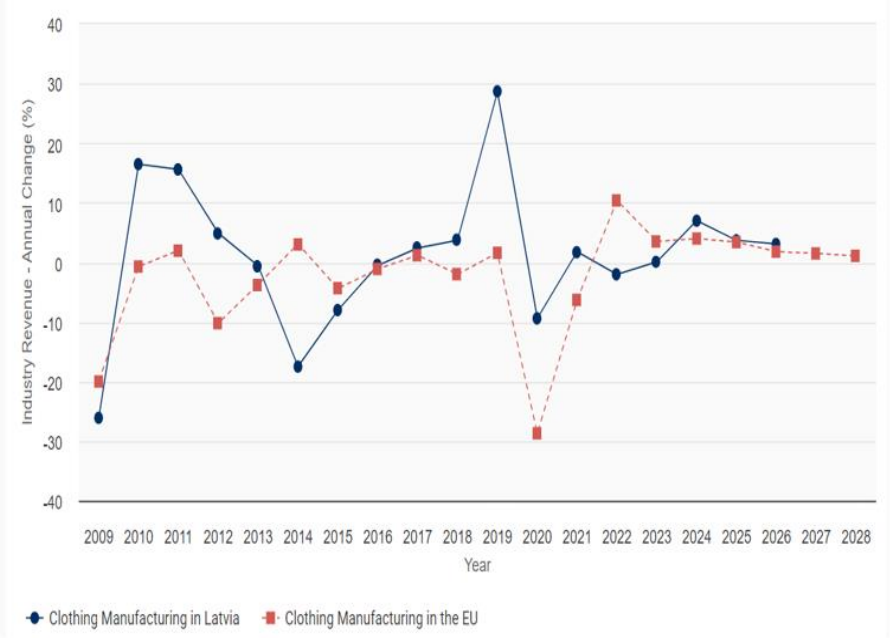

Figure 1. Comparison Chart Between Clothing Manufacturing of Latvia and Eu (IBIS world, 2022)

The figure 1 shows the statistics comparing the clothing manufacturing of Latvia and EU. The Clothing Manufacturing industry in Latvia has a valuation of €211.1m and is positioned 22nd among the 26 European Union countries in 2023. The industry's ranking has remained consistent since 2018, holding steady at 22nd place. In 2023, the Latvian clothing manufacturing sector ranks 68th among IBISWorld's 260 overall sectors

The authors of this research used questionnaire which was prepared using online platform Google Forms. The questionnaire consisted of 17 questions. The survey participants were Product Managers, Marketing Managers, Sales and Business Development Executives in textile companies, customers of textile company, academic researchers and Entrepreneurs of textile companies. The survey was focussed on the geographical areas of Latvia.

The questionnaire was divided into 3 different sections. The first section consists of general information related to survey respondent. The general information includes age, gender and profession. The second section consists of questions related to experience marketing strategies. The third section is dedicated to impacts of experience marketing on enhancing brand image of textile industries in Latvia. The questions 9 and 10 is related to impacts of experience marketing on the brand loyalty in the textile industry of Latvia. The questions 11 and 12 is related impacts of experience marketing on the brand perception of textile industry in Latvia. The questions from 13 to 14 related to impacts of experience marketing on customer retention. The remaining questions 15, 16 and 17 related to impacts of experience marketing on the brand identity, brand personality and customer satisfaction of textile industry in Latvia respectively.

The sampling method used in this research was the Convenience sampling. This method involves selecting people from the target group based on practical considerations such as ease of access, proximity, availability or their voluntary inclination to participate in the study. Convenience sampling involves selecting subjects that are readily available to the researcher. It is also called "occasional sampling" where subjects are selected based on their proximity to the researcher's location during data collection (Etikan et al., 2016). Altogether the number of respondents of the current survey reached 162.

All statements were assessed on a five-point LIKERT scale. Likert scale is a widely used measurement tool that was developed specifically to assess individuals' opinions, attitudes, or behaviours. The scale generally consists of a statement or question with a set of five alternative answer options. Participants choose the option that best fits their feelings or views about the statement or question. Likert scales are a useful tool for capturing accurate and detailed answers, as well as for assessing the level of agreement or disagreement on a particular topic. This is because they offer diverse options for respondents to choose from.

The authors conducted the Cronbach's alpha test on the results of the survey for testing its reliability and validity and obtained a score greater than 0.9 which suggests that the survey results are reliable.

The authors of this study analyse the survey data obtained from Google Forms using SPSS 28 software. Using this software, the authors conducted a Chi-Squared Test and the Spearman Correlation analysis. The Chi-Squared test is used for identifying the impacts of Experience Marketing on the Brand Image of the Latvian Textile Industry. The impacts were proved as a result of proving the several impacts of Experience marketing on the several aspects of brand image such as the Brand Loyalty, Brand Perception, Customer Perception, Brand Identity, Brand Personality, Customer Satisfaction.

4. RESULTS AND DISCUSSION

To know the profile of respondent, the first three questions are allotted which is from question 1 to question 3. The profile information includes age, gender and profession. The first question was related to age of the respondent. About 33.3% of respondents were from age group 18 to 24 and majority of the survey participants were from between 25 and 34. Only 1.2% were age over than 55. The second question was related to gender of the participants. The participants of the survey were majority women (56.8%) which was more than half of the total respondents. Males constituted 40.7%. 1.2% of respondents were from the category other and same percentage of people did not want to reveal their gender. The third question is related to profession of the participants. Various professions mentioned in survey questionnaire are product managers, marketing managers, sales and business development executives in textile company, academic researchers, entrepreneurs of textile company and customers of textile company.

Altogether the survey covered several blocks of questions – general attitude to experience marketing; impact of experience marketing on brand image in textile industry; impact of experience marketing on brand loyalty; impact of experience marketing on brand perception; impact of experience marketing on customer retention; impact of experience marketing on brand identity and brand personality; impact of experience marketing on customer satisfaction.

The impacts of experience marketing on the brand loyalty of the textile industry are checked by utilizing the Chi- Squared Test initially and the Spearman Correlation analysis later with the help of SPSS 28. In this test the authors checked for a statistically significant

relationship between the variable brand loyalty towards the variable experience marketing in the textile industry of Latvia (see table 1)

Table 1. Chi Squared test results for variable Brand Loyalty (Authors')

Chi-Square Tests			
	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	106.858	16	.000
Likelihood Ratio	93.474	16	.000
Linear-by-Linear Association	56.479	1	.000
N of Valid Cases	162		

As described in the table 1 above the "Pearson Chi-Square" group's results comprise the bulk of the investigation. The p-value for $\chi 2$ is 0.000, indicating that the findings is statistically significant. A P value below 0.05 signifies that there is a statistically significant relationship between the experience marketing strategies of the Latvian Textile Industry and brand loyalty. The following table 2 describes the interpretation of the spearman correlation values.

Table 2. Chi Squared test results for variable Brand Perceptions (Authors')

Chi-Square Tests			
	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	77.967	16	.000
Likelihood Ratio	76.240	16	.000
Linear-by-Linear Association	55.792	1	.000
N of Valid Cases	162		

As described in the above table the Significance value of the variable Brand perception is 0.000 which is less than 0.05 the threshold value. Thus, it can be quantified that the Experience marketing has significant impact on Brand perception. The Chi Square results can be used only to check whether the variables have a statistically significant relationship.

Table 3. Chi Squared test results for variable Customer Retention (Authors')

Chi-Square Tests			
	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	87.238	16	.000
Likelihood Ratio	84.225	16	.000
Linear-by-Linear Association	52.840	1	.000
N of Valid Cases	162		

As explained in the table above, the significance value in the column Asymp. Sig (2 Sided) is 0.000 which is less than the value of 0.05. Thus, it can be concluded that the Customer Retention has a statistically significant relationship with the Experience Marketing Strategies.

Table 4. Chi Squared test results for variable Brand Identity (Authors')

Chi-Square Tests			
	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	58.531	16	.000
Likelihood Ratio	58.185	16	.000
Linear-by-Linear Association	39.958	1	.000
N of Valid Cases	162		

As seen in the table above the results can be said as statistically significant since the value of significance is 0.000 which is less than 005. Thus, the variable Brand identity has a significant relationship with the variable experience marketing strategies.

Table 5. Chi Squared test results for variable Brand Personality (Authors')

Chi-Square Tests			
	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	73.564	16	.000
Likelihood Ratio	79.435	16	.000
Linear-by-Linear Association	49.782	1	.000
N of Valid Cases	162		

As described in the table 5 above, the significance value is 0.000 which is less than 0.05 and hence it can be deduced that the value is statistically significant and hence the variable can be accepted. Therefore, the experience marketing strategies has an impact on the brand personality.

Table 6. Chi Squared test results for variable Customer Satisfaction (Authors')

Chi-Square Tests			
	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	98.269	16	.000
Likelihood Ratio	94.631	16	.000
Linear-by-Linear Association	63.949	1	.000
N of Valid Cases	162		

As seen in the above paragraphs and tables, in this case also the significance value is less than 0.05 which is 0.000. This indicates that the Chi Square test proves the significant relationship between the variables Experience marketing and the customer satisfaction.

After performing the Chi Squared tests, there followed the Spearman correlation analysis for each variable. The summary results can be seen in figure 2.

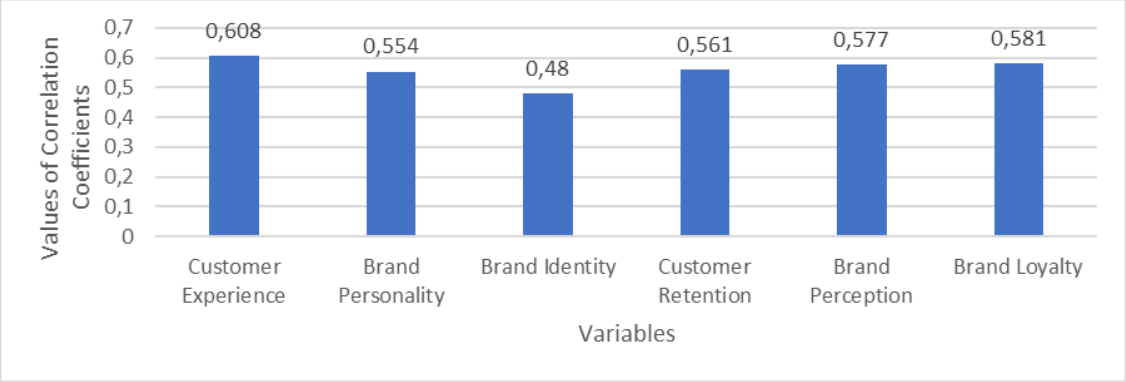

Figure 2. Summarization of the Correlation Coefficients of Independent Variables (Authors')

In the figure 2 depicted above and from the analysis performed by the authors, it can be deduced that the experience marketing strategies has a moderate positive impact on the several aspects of brand image except for the variable customer satisfaction. For the variable customer satisfaction, the value is 0.608 and hence the experience marketing has a strong positive relationship with the variable customer satisfaction.

5. CONCLUSION

The survey on the google forms were performed using the selected experts in the field of marketing and advertising in the textile industry yielded a sample size of 162 responses obtained using snowball sampling. The authors conducted the Cronbach's alpha test on the results of the survey for testing its reliability and validity and obtained a score greater than 0.9 which suggests that the survey results are reliable.

The results of chi square test conducted on the survey data revealed that the dependent variable experience marketing strategies in the Textile Industry of Latvia has a statistically significant relationship with all the independent variables.

Based on the findings of the Spearman Correlation study and the resulting model, customer satisfaction is the dependent variable in experience marketing that exhibits a robust positive correlation.

It can be deduced that the experience marketing strategies has a moderate positive impact on the several aspects of brand image except for the variable customer satisfaction. For the variable customer satisfaction, the value is 0.608 and hence the experience marketing has a strong positive relationship with the variable customer satisfaction. In order to retain consumers in the fashion retail industry, Latvian companies must modify their experience marketing strategies in response to increased competition. Due to the rapid evolution of fashion, there is a demand for luxe items that are reasonably priced. This requires the companies Latvian textile industry to provide intangible advantages alongside their superior products. Purchasing, utilising, and observing the products of the brand collectively constitute the brand experience. It is the most essential factor in generating revenue.

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PREDICTORS OF THE LAYOFFS IN THE SYSTEM OF PROVISION OF THE PERSONNEL STABILITY

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Abstract: The article substantiates the necessity of forecasting layoffs in the system of ensuring the stability of the company's personnel, especially in the conditions of the war in Ukraine. It has been established that the war in Ukraine significantly disrupted the stability of company personnel: 22% of respondents lost their jobs due to the war, 8% due to company destruction or bankruptcy, and an additional 1% of personnel was relocated. According to the results of an expert survey, the factors that most often lead to personnel dismissals were determined. The structure of predictive analytics for predicting layoffs and preventing staff turnover is defined. Based on the results of the expert survey, predictors were identified that signal probable dismissals and violations of personnel stability. The most important predictors of personnel layoffs are: non-competitive wages; lack of salary growth in accordance with the complexity of the work; excessive staff turnover in general (which indicates employee dissatisfaction); reduction of the general wage fund; increase in working hours.
The implementation of social technologies of HR management in order to prevent excessive dismissals and create a positive image of the company on the labour market is proposed.

Keywords: provision, personnel, predictors of layoffs, personnel stability.

1. INTRODUCTION

Globalization of the economy leads to an intensification of competition for human resources, which causes a structural imbalance of demand and supply of labour and changes in the competence structure of human resources in different regions of the world. The war in Ukraine significantly affected both the domestic and the international labour market, caused a catastrophic migration of workers from Ukraine (According to Libanova & Pozniak, 2023, as of April 2024, migration from Ukraine amounted to 6 million people).

These trends affect companies' ability to ensure the staff, retain qualified employees and prevent layoffs. This actualizes the issue of ensuring the stability of the company's personnel,

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in particular, identifying markers that signal possible layoffs. Therefore, one of the urgent tasks is to ensure the stability of company personnel as a manifestation of their ability to form a stable workforce, take into account the interests and goals of employees, and provide each employee with the opportunity for professional and personal development.

The Ukrainian labour market is currently characterized by imbalance and heterogeneity across regions of Ukraine (including temporarily occupied territories), differentiation of the professional-quality structure and, depending on the segment, may have signs of both a seller's market and a buyer's market. Unjustified and unbalanced personnel costs are high for companies: according to experts, replacing the right qualified specialist can exceed his salary in three years, and finding the right candidate takes precious time.

This highlights the importance of predicting layoffs within the framework of staff stability, utilizing a system of specialized predictors to identify employees' intentions to seek new employment and implementing measures to prevent this as one of the strategies for maintaining staff stability.

The investigations into ensuring personnel stability, particularly its measurement and forecasting, still require further research. Ideally, issues related to staff sustainability should be addressed within the framework of resilience measurement using a system of indicators, and efforts should be made to prevent breaches in staff resilience by mitigating excessive turnover and avoiding redundancies. Some authors (Zakharova, 2012; Kasych et al., 2020) approach the provision of personnel stability from the perspective of labour sociology, overlooking the individual as the primary asset of the company and the necessity of creating favourable conditions for staff development. In this context, only the implementation of modern HR practices in personnel management processes, coupled with the integration of psychological management trends, can guarantee the stability of the company's personnel and minimize its violations.

2. LITERATURE REVIEW

Ensuring the stability of a company's personnel is a pressing issue both globally and within the context of Ukraine's current situation. Ukraine is currently facing significant depopulation due to the ongoing war, with approximately 20% of its territory occupied, resulting in substantial losses to its industrial and human resources. According to Libanova and Pozniak (2023) an estimated 6 million Ukrainians have emigrated, with approximately 1.2 million people in Russia and Belarus and 500,000 people outside of Europe. Among the displaced, about one-third are children under 18 (2 million people), 6% are retirees, and two-thirds are of working age. Of the working-age population, 20% are men and the remainder are women. Consequently, between 3.5 and 4 million able-bodied Ukrainians have been displaced, while the current population of Ukraine is estimated at around 32 million people. This depopulation poses significant challenges for businesses both during wartime and in the subsequent period of economic recovery, underscoring the importance of ensuring personnel stability.

Ensuring the stability of a company's personnel is a focal point for sociologists, demographers, managers, and psychologists. Additionally, Bezugla, (2018) define staff resilience in their work and provide indicators for its evaluation. Trunina et al. (2020), offered a diagnosis of personnel stability; while Vartanova and Povzun (2023) developed an ontology for personnel stability. However, the problems of forecasting layoffs in the system of provision of personnel stability require further research.

3. DATA AND METHODOLOGY

The analysis of approaches to the predictions of the layoffs in the system of provision of stability of personnel, presented both in domestic and foreign scientific sources, has enabled us to formulate the conceptual vision of provision of the stability of personnel as a certain dynamic state of personnel management system, which characterizes its ability to maintain performance under the influence of internal and external disturbances, which is evaluated by a balance of quantitative and qualitative parameters. The stability of the personnel is determined by the employer's ability to provide competitive conditions for the development of the staff as their correspondence to the sphere of industry, specialty, other companies and complexity of tasks performed.

Based on an author's understanding of provision of stability of personnel, the goals of its measurement, methods of analysis, evaluation and pronunciation are determined. The most common approach to measuring the resilience of personnel is the use of a system of indicators of staff turnover, its stability, mobility and structure, which determine the stability of the staff and identifies its disruption. However, the results of measuring stability of personnel do not make it possible to predict its change. For this purpose, we propose to use a system of predictors to measure staff's resilience, which allows us to identify the most probable causes that lead to the dismissal of personnel. These predictors should be considered as part of predictive analytics used in sustainability system.

As a methodological basis for identifying the predictors of the layoffs in the system of provision of stability of personnel, we used an expert survey method to identify the most common markers of staff's resilience by interviewing respondents of different age groups, professions and specialties. In order to find ways to prevent staff overflow in the context of provision on its stain ability, the author conducted an online research: "Sustainable Staff Development: Factors and Methods of Provision" (May-December 2022), using Google Forms tools. The purpose of the research was to determine the factors of ensuring and violating personnel sustainability, motivators and demotivators of personnel, as well as the factors that determine the desire / unwillingness to work in the company, identification of predictors of violation of sustainability of personnel development. Representatives of different age groups, educational level, sectoral affiliation and different regions of Ukraine participated in the survey. The total number of respondents was 89.

4. RESULTS AND DISCUSSION

Changes in approaches to personnel management of the company, taking into account, on the one hand, the requirements of employers, and on the other – the requirements of jobseekers, necessitate the provision of sustainable development of company's personal on the basis of prevention of staff turnover and formation of a system of predictors of dismissal of personal. This allows to prevent unpredictable dismissals of personnel, identify the reasons for dismissal of staff, partially protect the personnel of the company from unpredictable dismissals, improve the productivity of personal, ensure a positive image of the company in the labour market. According to HR-specialists (Vartanova & Povzun, 2023) it is known that:

- 80% of employees are recruited in accordance with their professional and technical skills, but in 80% of cases personal are dismissed due to their negative attitude towards their work and colleagues;
- valuable employees often leave the company because of conflicts with the immediate manager;
- a qualified person may be a conflict person or an ineffective manager;

- employees are fired after a probationary period because they are not satisfied with the team, corporate culture or manager;
- the cost of replacing a sales manager or sales specialist may be higher than his / her 3-year salary;
- the cost of replacing an ordinary employee with a salary of $ 1,400 per month, according to experts of one of the largest US banks, is $ 51,000.

Companies that are actively investing in the evaluation, selection, training and development of staff have achieved (Bezugla, 2019):

- more than 50% growth in services as well as customer satisfaction compared to competitors;
- an increase of 60% – 300% higher than its competitors;
- sales revenue is 200% – 300% higher than its competitors.

According to specialists representing personnel companies, the main reasons for the dismissal of personnel are inability to grow, work overload, uncertain professional prospects, undervaluation, lack of motivation, lack of confidence or excessive hierarchy (*7 reasons for the liberation of even the best employees at their own will, 2020).*

The main reasons for the dismissal of personnel are: low wages (50.0%), stagnation in career, lack of development (45.0%), a job offer in other companies (39.0%), lack of interest in work (33.0 %), uncomfortable and toxic atmosphere in the team (32.0%). There are also other, more hidden and sometimes undeclared reasons for dismissals: incompatibility with other people, conflicts, a person's low level of professionalism, slowness, discrediting oneself in front of colleagues or clients, negligent attitude to one's duties, irregular working hours, lobbying of "their own" in companies, sexual harassment in the workplace, conflict of interest, layoffs, regular fines and disciplinary sanctions, loss of trust, inaccurate data or forged documents when hiring and other reasons (Vartanova & Povzun, 2023). The main reasons for the dismissal of personnel (according to the Work.ua Ukrainian Portal) are presented in Figure 1.

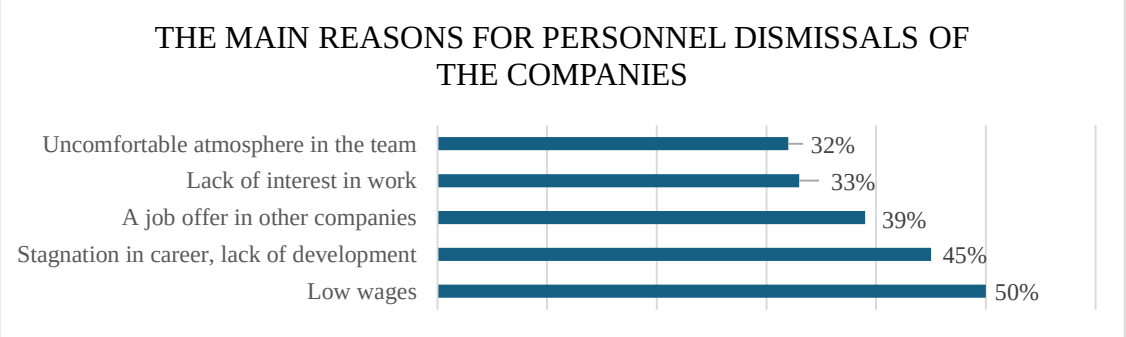

Figure 1. The main reasons for personnel dismissals of the companies (*Source:* Work.ua Ukrainian Portal)

According to the results of our study, the reasons for layoffs of the company staff were revealed, which are shown in Figure 2.

Therefore, the reasons for respondents' dismissals are varied. Conditionally they can be divided into hygienic and situational factors. Most of the dismissals were due to hygienic factors violations: 43.3% of respondents were dissatisfied with their wages; 35.8% – lack of career perspective; 22.4% – working conditions; 16.4% – unfavourable atmosphere in the team; 13.4% – meaningless or uninteresting work; 9.0% of respondents were dissatisfied with informal employment and lack of freedom to make decisions; 7.5% – hard or uncomfortable work schedule, 1% – distance from home. Situational factors include changing the place of work: the

war in the Ukraine – 22.0%, more interesting job offers – 3.0%, Company Restructuring, Destroying or Bankruptcy – 8.0%, childcare leave – 2.0%, relocation – 1.0%.

These results indicate that the prevention of excessive staff turnover allows us to preserve the work potential, unity and cohesion of the team, and in general to ensure the sustainable development of the personnel of the enterprise. In sociology of work, these concepts are combined by the interconnected terms "fluidity", "stability" and "resilience" of personnel.

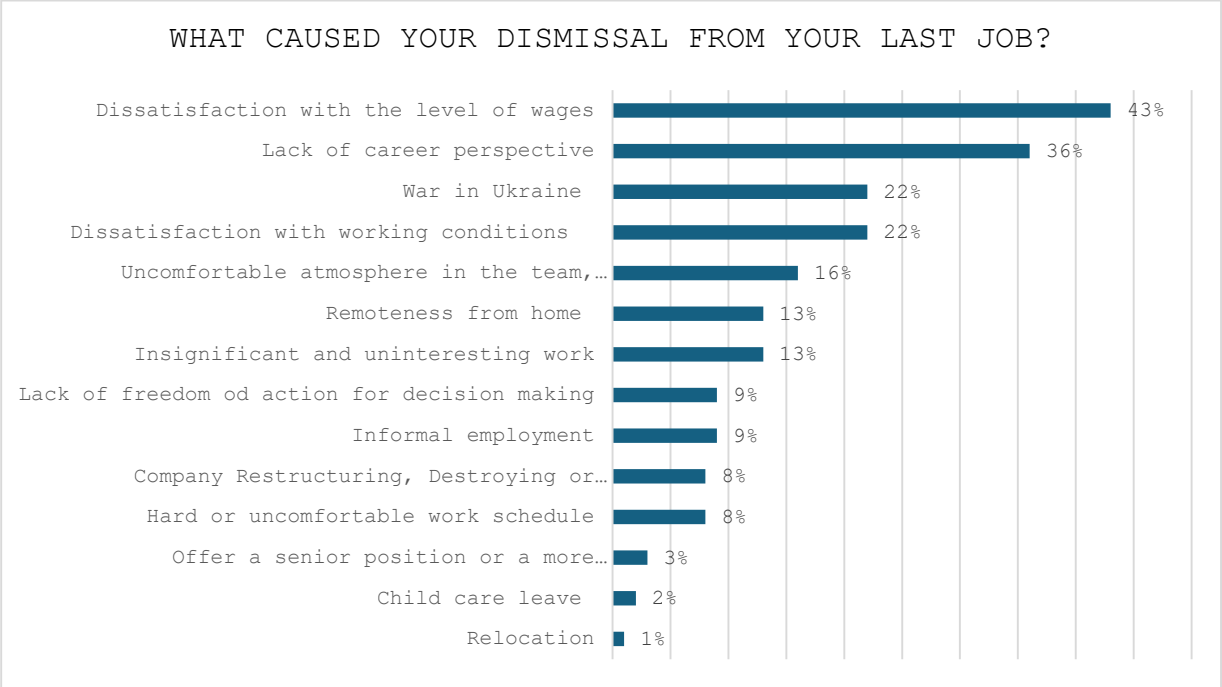

Figure 2. The reasons for dismissal from the last place of work (*Source: own research*)

Under staff turnover is understood the socio-economic process of spontaneous change in the personal composition of employees of enterprises for a fixed period of time under the influence of various social, economic, psychological and other factors. Fluidity is based on the inconsistency or contradiction between the interests of the individual and the ability of the enterprise to realize them. The staff turnover includes all dismissals of employees at will and dismissal for violation of labour discipline.

It should be noted that staff turnover reduction alone cannot be considered as the primary purpose of ensuring the sustainability or stability of staff development. Specialists refer to the normal turnover of 8-10% of the average number of employees. The enterprise is undesirable as excess (12-25% per year) and low staff turnover (3-5%). In the first case, it leads to the destabilization of workforce, in the second – to its aging, which hinders the restoration of quality staff (education, real qualifications, intellectual abilities, physical skills, psychological stability, production experience) (Vartanova & Povzun, 2023).

Traditionally, in the practice of enterprise activity, staff turnover is evaluated as a negative factor, which is associated with the material costs associated with the selection and involvement of staff, the adaptation period of a new employee, which violates the sustainability of the company staff. However, it should be noted that staff turnover and turnover are natural processes, which allows updating the team and getting rid of personnel ballast in a timely manner. And the low level of variability of personnel slows down the development of personnel, leads to excessive aging of the team, reducing its creative potential. In this context, increasing

staff turnover and turnover is a natural and inevitable phenomenon that can have positive effects.

The process of ensuring the sustainability of personnel involves, according to the understanding of sustainability, the management impact on both quantitative and qualitative parameters of sustainability. The impact on quantitative parameters is to select the most important for the company indicators of staff sustainability (indicators of staff turnover, structure, turnover, mobility, etc.) and keeping these indicators within the specified limits.

A more interesting feature of HR managers is to analyse and forecast redundancies, identify and prevent situations that lead to staff resilience. This is done by forming and analyzing employee profiles, identifying those who are about to leave, and working with them accordingly. The data obtained serves as the basis for predictive analytics and the construction of predictive models for preventing staff resilience. Working with employees who are about to leave is meaningful from two points of view: first, it will identify the reasons for the employee's motivation impairment and allow him / her to remain in the company; Secondly, even if the employee's decision to leave is unshakable, interviewing him allows to obtain information about the reasons for leaving the company and other important information, to maintain good relations with the co-worker and to prevent the disclosure of trade secrets or other losses to the company after him. Dismissal creates the image of a responsible and socially oriented employer.

The decision to quit is usually not made instantly. Usually, it takes some time (usually two to three months) between making the decision to realize and the realization itself. The employee accumulates the critical mass of dissatisfaction: the level of remuneration, development and career prospects, working conditions, quality of work, relationships with management and colleagues, and other factors, and finally decides on dismissal.

Predictive analytics for personnel dismissals relies on various sources of information:

- Information on employees who are resigning or considering resignation is collected to analyze the reasons for their departure and their new employment opportunities. This data helps identify the strengths and weaknesses of the employer, assess the competitiveness of working conditions and employee development, and evaluate the company's ability to attract and retain staff.
- Comparing the HR profiles of terminated employees with those of current employees can reveal common characteristics and potential indicators of an employee's intention to leave. HR profiles of employees still with the company but considering resignation offer insights into retention strategies for key staff members.
- Employee data includes information on their specialty, qualifications, work experience, training, awards, evaluations, and career growth plans. This information is sourced not only from HR profiles but also from other departments and systems such as finance, CRM, email, corporate portals, office access control systems, and social media profiles. Utilizing diverse data sources enhances the accuracy of predictive models.
- Behavioral characteristics of employees should also be considered. Specific behavioral changes, such as taking extended vacations, reduced interest in work tasks, decreased sociability, and limited communication focused solely on work matters, may indicate an intention to change jobs.

According to the results of the survey, predictors were identified that could indicate possible dismissal of employees (Figure 3).

Therefore, the most informative predictors of probable dismissal include:

- employee salaries are uncompetitive compared to the average in the market or industry;
- remuneration does not increase in accordance with the complexity and number of tasks performed;

- there is an excessive turnover of staff as a whole at the enterprise or unit (which indicates employee dissatisfaction);
- employees take unplanned vacations using previously unused parts (the employee needs time to find a new job);
- the wage bill as a whole of the enterprise or unit is reduced;
- the total number of unit staff is decreased (which may indicate that this trend will continue in the future);
- extra working hours are increased.

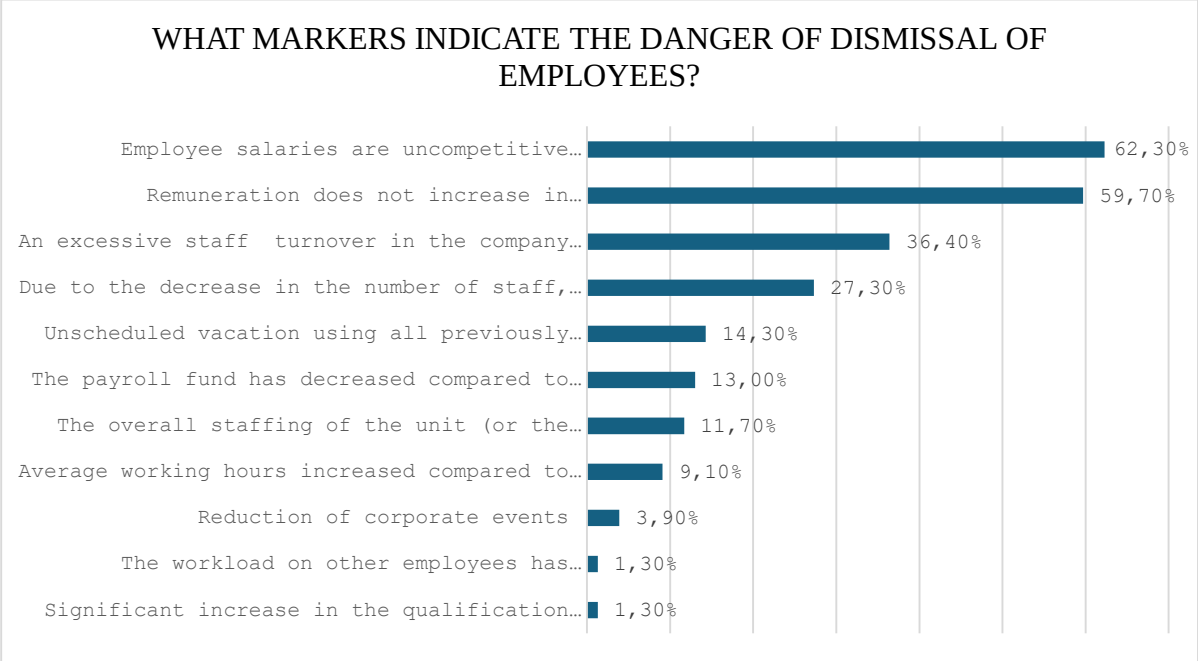

Figure 3. Predictors of employee dismissal (*Source: own research*)

5. CONCLUSIONS

Analyzing the predictors of staff dismissal in the context of ensuring its sustainable development, the following conclusions are drawn:

1. Ensuring the stability of the personnel of the enterprise requires its assessment and forecasting. Assessment of staff resilience is to provide the desired level of quantitative and qualitative criteria that characterize the resilience of staff. Staff resilience assessment is proposed based on the use of a system of indicators of staff turnover, stability, mobility and turnover, which makes it possible to determine the resilience of staff and to identify situations of disruption. Qualitative criteria characterize the conditions of personnel development of the company (conditions and work, competitiveness of the salary level, the ability to make independent decisions, relationships with colleagues and management, atmosphere in the team, etc.). It is recognized that staff resilience depends on ensuring competitive conditions for staff development.

2. Competitiveness of the conditions of personnel development is their correspondence to the average in the branch, specialty, other enterprises and complexity of the tasks performed. If the average parameters of staff development are uncompetitive, it with 100% probability

leads to dissatisfaction with the conditions of work, its demotivation and increase of staff turnover, which generally violates the stability of the personnel of the company.

3. To ensure the sustainability of personnel, it is necessary to constantly monitor and predict its possible changes based on predictors of violation of personnel stability. This makes it possible to influence staff turnover, help maintain the company's personnel potential and create a positive image of the company in the labor market.

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CUSTOMER RELATIONSHIP MANAGEMENT IN THE BANKING SECTOR

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Abstract: Customer Relationship Management (CRM) represents a broader business strategy designed to reduce costs and increase profitability by enhancing customer loyalty. CRM is a concept whose implementation leads to customer retention, increasing their number, as well as enhancing the quantity and quality of services provided to these customers. It is both a management philosophy and a methodology for conducting business with customers. The methodology of this paper is based on the analysis of empirical data gathered using a standardized questionnaire that was administered in a bank industry. The most important result of research is the confirmation that it is possible to identify the main factors influencing CRM in modern organizations, as well as the criteria for the importance of the value system of employees regarding CRM. Additionally, the research results indicate a statistically significant difference in perceptions of banking services between customers and employees.

Keywords: customer relationship management, banking sector, business organization

1. INTRODUCTION

In a complex business environment characterized by rapid cycles of change and numerous factors determining an organization's operation, customer relationship management (CRM) strategy has emerged as one of the most critical elements for any business entity's survival. Considering the large number of competitive organizations in every economic sector, as well as the myriad of external and internal influences affecting daily operations, the importance of strategically nurturing customers through the CRM concept is growing. The CRM concept has stood out as a customer relationship management strategy that responds to modern business trends. Theory and practice increasingly recognize the long-established thesis that the focus of any successful business is the customer. Businesses can only achieve long-

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term successful growth by properly understanding customer needs, identifying and synthesizing all relevant information about past, present, and potential future customer behavior, and implementing awareness of these aspects. Given that customer needs are becoming more diverse and rapidly changing in today's environment, a good management system represents the conceptual solution. CRM is responsible for tracking changes in customer behavior, market shifts, marketing functions, and data storage technology (Diem et al., 2021).

Customer relationship management is an extremely dynamic and complex process that encompasses all elements and functions of an organization, as well as the entire organizational culture with all its values. CRM is not just a function, strategy, or way of doing business, but rather a comprehensive concept of modern business as a whole.

The research aims to determine customer relationship management in contemporary organizations by identifying the correct CRM factors with varying degrees of significance. The research places special emphasis on the banking sector and the relationships established between bank service users and employees in banking institutions.

2. LITERATURE REVIEW

The literature in the field of customer relationship management (CRM) is relatively recent. The concept of CRM has gained traction relatively recently, as evidenced by the issuance of most books, papers, and publications after the year 2000. This recognition underscores the need to manage customers specially, aiming to satisfy their needs, which ultimately leads the business organization toward long-term profitable growth.

It's important to highlight the role of three authors, Zeng, et al. (2003), who detailed what sustainable CRM entails through four key characteristics: increasing customer satisfaction, providing sales information, differentiating and personalizing services, and recognizing customer needs. According to Xu and Walton (2005), the most important part of implementing a CRM strategy is proving customer satisfaction, retaining existing customers, providing strategic information, and ensuring customer lifetime value. CRM assists businesses through a customer knowledge management strategy to focus on marketing principles and customer-oriented promotion, aiming to retain existing customers and acquire new ones, thereby increasing efficiency and reducing costs (Gil-Gomez et al., 2020). The information system is a critical aspect of CRM. The success of the entire CRM concept depends on good information support in terms of quality databases, technology, and applications (Naim, 2021).

Business success depends on efficient information exchange between customers and service or product providers. Communication tools that utilize information technology enable faster and two-way information exchange, providing an additional basis for co-creating value through CRM strategies (Itani et al., 2020). Chen and Popovich (2003) define CRM as the integration of technology, people, and processes when building long-term relationships with clients and stakeholders. Verhoef and Langerak (2002) have observed that marketing and technology are key components of CRM strategy. They note that CRM has deep roots in marketing but is always associated with software usage. According to these authors, CRM is based on three aspects of marketing management: customer relationship orientation, marketing, and marketing databases (Verhoef & Langerak, 2002). Customer relationship management encompasses strategies and technologies that enable tracking and managing data throughout the customer's lifecycle. In Sahoo's study (2020), the bank utilizes CRM to attract new clients by assessing the value they bring based on previously collected data. According to Yapanto et al. (2021), banks benefit from referrals from loyal customers and align their strategies with customer satisfaction. The importance of customer satisfaction is highlighted in determining long-term customer loyalty. Organizations gain competitive advantage through customer

loyalty, and to secure this, companies invest significant resources in product, service, and process innovations (Al-Okaily et al., 2022). The study by Magatef et al., (2023) shows that trust and commitment to the organization generate loyalty. Responding effectively to customer needs is crucial for retention and growth. Branch employees prioritize quick, efficient service delivery and building strong customer relationships. To maintain loyalty, businesses shouldn't compromise their partnership with customers (Yapanto et al., 2021).

To develop a quality relationship with customers, banks were among the first to adopt the CRM concept. The primary reasons banks adjust their business processes to meet customer needs are to retain existing customers and attract new ones, encourage customers to collaborate, and inform customers about their portfolio of products, services, and communication channels (Laketa et al., 2015). The study by Gopalsamy and Gokulapadmanaban (2020) discusses the relationship between CRM and customer satisfaction. A positive correlation suggests that an increase in these two factors leads to an increase in customer loyalty.

According to all of the above, CRM is a business strategy that enables organizations to understand their customers' existing and potential needs based on past experiences. This helps the organization predict its actions and potential demands. In today's business environment, where there is a highly developed digitalization of society as a whole, only those organizations relying on the CRM business concept will experience business success.

CRM will enable employees to correspond better, providing the most personalized service possible, which in turn increases job security with the customer. Thus, by implementing CRM, employees who come into direct contact with customers have good tools to collect and utilize more customer data to achieve a more profitable business with the customer, all through a proactive approach. In the case of a bank, managers involved in building customer relationships (such as account managers, relationship managers, advisors, etc.) will spend more time nurturing that relationship rather than resolving internal issues among employees within the branch related to service delivery to the customer (Madill et al., 2007). Al Duwailah and Ali (2013) assert that an organizational culture that prioritizes adaptive learning and customer-centricity can positively influence both internal collaboration and the organization's external relationships. Organizational culture refers to a set of assumptions, values, and beliefs held by employees within an organization. Organizational culture must value flexibility and adaptability while maintaining stability and control over positive values (Limaj & Bernroider, 2019). The culture of an organization manifests itself in its climate, and nurturing incorrect values can lead to employee dissatisfaction, further affecting performance and stakeholder relations (Paais & Pattiruhu, 2020). Values are key drivers of behavior and attitudes (Schwartz, 2012). Schwartz (1992) identifies eleven key values: Universalism, Self-direction, Stimulation, Hedonism, Achievement, Power, Security, Conformity, Tradition, Spirituality, Benevolence. Each of these values is defined by the sub-values it includes (Schwartz, 1992). The relationships among values are dynamic; certain values may conflict with others (e.g., the pursuit of change and traditional values), while others may be compatible (values of achievement and power) (Schwartz, 2012).

3. DATA AND METHODOLOGY

The research aims to explore customer relationship management (CRM) practices in contemporary organizations, with a particular focus on the banking sector. It delves into the relationships that form between banking service users and banking institution employees.

The study seeks to identify the processes that define CRM in modern organizations, assess their impact on organizational operations, and examine their feedback effects on employees and management.

The research encompassed two key aspects:

- The relationship between a modern business organization, viewed through the lens of a bank, and banking service users, which will contribute to identifying the key significant factors defining CRM.
- Examination of the key values that determine the significance of CRM factors in a modern business organization.

Based on the defined objectives, the research sets the following hypotheses:

Hypothesis 1 (H1): *The main factors influencing customer relationship management in a modern organization can be identified.*

Hypothesis 2 (H2): *There is a statistically significant difference regarding banking services between bank service users and bank employees.*

Hypothesis 3 (H3): *It is possible to determine the criteria for the significance of bank employees' value system in relation to CRM.*

3.1. Sample

The research was conducted by distributing questionnaires to employees of ten different banks as well as to users of banking services. The sample consisted of a total of 94 respondents, with 40 bank employees (42.6%) participating who work in positions directly or indirectly related to clients and 54 banking service users (57.4%) who were randomly selected from across Serbia.

3.2. Instrument

To collect as accurate data as possible for the research, we used two questionnaires:

- CRM Questionnaire (Milisavljević, 2012) – answered by respondents from both groups: bank employees and users of banking services.
- Schwartz's Work Values Questionnaire (Schwartz, 1992) – answered only by bank employees.

The CRM questionnaire contains 39 questions with provided answers in the form of a five-point Likert scale (1 - strongly disagree; 2 - disagree; 3 - neither agree nor disagree; 4 - agree; 5 - strongly agree) to determine the quality and intensity of the measured indicators.

The instruments, designed to achieve multidimensionality, measure the state of CRM elements within the organization, the presence of TQM principles in the organization, and the degree of user individualism satisfaction.

Three dimensions, or three significant factors, were identified in the questionnaire:

- Development of customer relationship management
- Alignment of business with management principles
- Individual approach to customers

Schwartz's Work Values questionnaire contains 56 questions with provided answers. Again, a five-point Likert scale was used (1 - not important, 2 - slightly important, 3 - important, 4 - very important, 5 - of crucial importance) to determine the quality and intensity of the measured indicators. When creating the instrument, it was envisioned that the scale would be multidimensional, which was respected by using Schwartz's (1992) proposed key. The following 11 dimensions were identified: Universalism, Self-direction, Stimulation, Hedonism, Achievement, Power, Security, Conformity, Tradition, Spirituality, Benevolence. The questionnaires used had already been constructed and were adopted by the mentioned authors, given that they had been empirically tested.

4. RESULTS

Table 1. Descriptive indicators for variables

	M	SD	Me	IQR	Min	Max	Skewness	Kurtosis
Universalism	28.65	4.464	29.00	6	20	38	.187	-.200
Self-direction	23.23	3.309	23.50	5	18	30	.234	-.801
Stimulation	9.82	2.062	10.00	3	6	14	.266	-.357
Hedonism	7.10	1.317	7.00	2	4	10	.091	-.011
Achievement	19.05	2.873	19.00	4	15	25	0.412	-0.757
Power	11.83	2.782	12.00	5	8	18	.438	-.680
Security	26.95	3.297	28.00	5	16	32	-1.178	2.015
Conformity	15.38	2.084	15.50	3	12	19	.043	-.908
Tradition	14.98	2.851	15.00	4	9	21	.145	-.168
Spirituality	16.50	2.828	17.00	4	10	22	-.140	-.536
Benevolence	29.95	4.723	30.00	7	21	39	-.058	-.763
Development of customer relationship management	70.13	8.913	68.00	11	50	90	.360	.320
Alignment of business with management principles	59.050	7.9870	58.000	8.8	43.0	79.0	.384	.145
Individual approach to customers	15.25	2.181	15.00	3	10	20	.162	-.030

Table 1 provides descriptive statistics by scales. The results were obtained by summing up the rows, followed by providing the descriptive statistics for that sum, i.e., the scale. For example, universalism consists of 8 questions, the mean (M) is 28.65, and when we divide that value by 8, we get 3.58 as the arithmetic mean of all the given responses from all respondents for questions belonging to this subscale.

In the case of this questionnaire, we can conclude that the scales are relatively symmetrical, except for the Security scale. Since that value is notably negative, it can be inferred that respondents have a unique stance that this factor is indeed important to them (scores are quite close to the right end of the scale, i.e., 4-5). The value of kurtosis for Security is prominently pronounced. As the kurtosis value is notably positive, it can be concluded that respondents have a unique stance that this factor is indeed important to them (a "sharp" peak is formed approximately at 4-5). In conclusion, considering the values of skewness and kurtosis, it is concluded that Security is prominently highlighted as a very important factor for the respondents.

The values encompassed by the Security scale are national security (protection of the nation from enemies), reciprocity in services (avoiding debt to someone), sense of belonging (feeling that others take care of me), social order (stability of society), cleanliness (neatness, refinement), health (being physically and mentally healthy) and family security (safety for loved ones) (Schwartz, 1992). Taking into account the environment in which the respondents operate (Serbia – a country that has recently undergone an extremely turbulent period), it's clear that uncertainty and insecurity, as the main opponents to the value of Security, are what employees most want to avoid. The results indicate that this value is indeed the most significant factor influencing the success of CRM factors within an organization.

In the presented results, the customer relationship management development scale with an IQR = 11 indicates that respondents have quite varied opinions, whereas the individual approach to customers with an IQR = 3 indicates a view closer to consensus among the respondents.

4.1. Differences in scores

Using an independent samples t-test, it was found that there is a statistically significant difference between bank employees and users of their services in scores on:

- Individual approach to customers ($t=2.311$, $p<0.05$, $M_B=15.25$, $M_K=14.09$)
- Customer relationship management development ($t=2.983$, $p<0.01$, $M_B=70.13$, $M_K=64.15$)

These quality dimensions are rated more positively by bank employees. Respondents belonging to providers of banking services consider certain CRM characteristics to be at a higher level than the customers themselves perceive. The awareness of a bank employee is, so to speak, programmed towards these differentially higher values, but, we can safely conclude that they do not represent the real picture perceived by the users of these services. In the case of "Alignment of business with management principles", it was shown that there is no difference in opinions between the two tested groups. More precisely, differences do exist ($M_B=59.050$ $M_K=58.907$), but they are not statistically significant. Therefore, it can be said that both groups have an equal rating for this item.

4.2. Differences by items

The Mann-Whitney test was used in this case as a suitable method for analyzing differences between two independent groups (bank employees and users of banking services). The interpretation of all statements focuses on those where there is a statistically significant difference in opinions. For example, for the variable "Real client demands are adopted in the bank", it was shown that there is no difference in opinions between bank employees and banking service users ($p = 0.581$, $Z\ p = -0.552$). Differences in the arithmetic mean values between groups do exist ($M_b = 3.7$, $M_k = 3.54$) but they are not statistically significant. In contrast, for instance, with "Efforts are constantly made to meet the wishes and needs of clients", such a difference is statistically significant ($p = 0.012$, $Z = -2.507$), with bank employees giving higher ratings on this item ($M_b = 4.13$, $M_k = 3.59$). Statistically significant differences are also found in statements like “Client questions are analyzed with special care”, “Bank employees are always available to clients”, or “Loyalty and satisfaction of clients are constantly measured”.

Ultimately, bank employees are more biased when evaluating their work. Given the significant difference in arithmetic mean values, bank employees likely believe they are doing their jobs better. However, clients rate this aspect slightly lower and evaluate this item more "strictly".

4.3. Schwartz values

Positively rated values (top 10 values):

- Family Security (safety for loved ones)
- Health (being physically and mentally healthy)
- Self-respect (belief in one's worth)
- Intelligence (being logical, thoughtful)
- Inner Harmony (peace with oneself)
- Independence in Setting Personal Goals (freedom in finding purpose)
- Courtesy (politeness, good manners)
- Capability (competent, effective, efficient)
- Respect for Parents and Elders (esteem)
- Responsibility (support for others, reliability)

Negatively rated values (bottom 10 values):
- Religiosity (holding onto religious beliefs and faith)
- Disconnectedness (from global trends)
- Power (right to leadership and command)
- Control (dominance, control over others)
- Wealth (possessions, money)
- Humility (humbleness, demeaning one's desires)
- Exciting Life (stimulating experiences)
- Reconciliation (coming to terms with life circumstances)
- Respect for Tradition (preserving outdated customs)
- Bravery (seeking adventures, taking risks)

Higher arithmetic mean values for the top ten indicate a "pile-up" on the right side of the scale towards higher ratings. Conversely, for the bottom ten values, there is a "pile-up" on the left side of the scale, closer to lower ratings.

5. DISCUSSION

The following section will elaborate on the hypotheses based on the obtained research results. These results will provide insights into the validity and implications of the set hypotheses.

H1: *The main factors influencing customer relationship management in a modern organization can be identified.* The results confirmed the general hypothesis that it is possible to determine the factors influencing customer relationship management in a modern organization. The research encompassed both sides of the customer relationship to obtain an objective picture of the actual factors. Besides identifying the factors, the research also showed the significance of individual factors in the general category of customer relationship management, their mutual correlation, and the direction each factor should aim for to, together with other elements, contribute to the long-term successful operation of each business organization.

H2: *There is a statistically significant difference regarding banking services between users and bank employees.* The hypothesis has been confirmed. On average, bank employees rate CRM factors more positively than the same service's users. Bank employees systematically rate their awareness at a higher level than users of the same services do. The research has shown that the image a bank and its employees hold of their organization is not critically set but rather quite subjective. This leads to the conclusion that the bank must continue to work on developing CRM factors that better align with users' needs on one hand, and parallelly lead the bank towards long-term successful market survival on the other.

H3: *It is possible to determine the criteria for the significance of bank employees' value system in relation to CRM*. The hypothesis has been confirmed. The research has shown that bank employees rate the values with the highest scores as important elements of CRM. The research has also confirmed in the banking system that the value of Security is the most significant factor influencing CRM. By the value of Security, we mean national security (protection of the nation from enemies), reciprocity in services (avoiding debt to someone), sense of belonging (feeling that others take care of me), social order (stability of society), cleanliness (neatness, refinement), health (being physically and mentally healthy), and family security (safety for loved ones). For citizens, as well as for employees in the banking sector, it is extremely important to feel safe, without thoughts of war, with stable social order and a sense of belonging. The primary need is safety for their family and the most basic living conditions, both in the working and private environment. Any institution that bases its operations on these

values for its employees and then builds upon them with other secondary values, will have great prospects for long-term successful business supported by satisfied employees.

6. CONCLUSION

In modern business conditions, where we are daily overwhelmed with a multitude of information that needs to be accepted, analyzed, and distilled, it is necessary to establish and nurture a system that will effectively respond to every individual and group participating in the market competition. Given that the main market battle is always fought around who is at the center of every business organization's operation – that is, the customer of products or services – it is extremely important to form a model that will manage customers – CRM.

The research confirmed the general hypothesis (H1): *It is possible to identify the main factors influencing customer relationship management in a modern organization*. Research in the banking sector among employees on one side and banking service users on the other side unequivocally points to significant CRM factors, their correlations, levels of relevance, etc. Any banking organization that intensively works on improving the CRM model can hope for business development in the future. It is very important to note that the key to successful implementation of the CRM concept is good and continuous education of employees about the application of this model, as well as regular motivation to adopt this concept.

Based on the conducted research, we juxtaposed the views obtained from employees on one side and users on the other. This led us to a true, real, and truthful measure of the significance of individual elements and factors influencing the success of CRM and the entire organization. H2 is confirmed: *There is a statistically significant difference regarding banking services between users and bank employees.* Bank sector employees significantly rate CRM factors more highly when providing their banking services compared to how users view the same services. Users indicate which factors are of high importance, and these are guidelines for possible further development of CRM in banking. The goal is to collaborate with an absolutely satisfied customer, providing them with banking services that best meet their needs at all times, because only such a business concept leads to a long-term successful and profitable operation.

In the research, we also dealt with the value system of employees in organizations and determined the exact values that significantly and positively influence the success of CRM elements, as well as those that have an insignificant and negative impact. H3 is confirmed: *It is possible to determine the criteria for the significance of bank employees' value system in relation to CRM*. Every bank's management should prioritize a thorough understanding of its employees' value system in order to nurture significant values, with the ultimate goal of fostering good motivation for the implementation of the CRM model.

Customer relationship management is an extremely important category in every modern organization. Considering that CRM is not just a function, nor an organizational part, nor a mere information system that only stores various data, it is essential to conclude that the only correct way to look at CRM is as a comprehensive business concept in the modern world. Every CRM is tailored to a specific organization, but they all have multidimensional capabilities and link all employees of a business entity with multifaceted customer information synthesized through reports, data, relationships, campaigns, sales opportunities, stages of the business process, internal communication, business histories, delegated plans, notifications, and similar features that can be multiplicatively upgraded in a well-designed information system.

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Original Research

NETWORK OPERATION CENTER FOLLOWING PROCEDURES

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Abstract: We live in a digital landscape. In them, seamless communication, and the right information have become crucial. This paper describes the Network Operation Center – NOC, which tasks to manage, protect, and monitor important information. NOC must supervise all types of equipment, networks, servers, databases, and firewalls. Our subject of study and organization in this paper is NOC Transmitters and communication (ETV). The function of NOC ETV is the continuous monitoring of the system to ensure its continuity function, with the ultimate goal of raising the level of user satisfaction. This is achieved by timely reaction in the event of an incident in the ETV network which consists of a set of activities. Those set of activities we will describe and explain. Activities establish a connection by calling center, network component maintenance service, and crews on broadcasting stations ETV and teams on the field. All this makes this process very complex, but the procedures and methods for its solution give excellent results. In that way, the goal of acquire confidence in the company as a †reliable and professional partner. Good management of NOC gives us good satisfaction in reducing equipment failures. The NOC plays an important part in improving the company's customer focus and ultimately, improving customer satisfaction and experiences.

Keywords: Network Operation Centre, supervise, protect, networks, equipment.

1. INTRODUCTION

Employees at the facility monitor weather conditions, the status of the company's services, and much more from their desks, and by gazing up at the massive screens pictured above (Jeff Cornier, 2011). It is a description of a modern monitoring centre, and in addition to everything listed, there must be also procedures, instructions, forms, standards, and goals that we need to fulfill. NOC needs to establish the goals of the system and the processes that make it up, as well as the resources needed to deliver the result according to the user's requirements and policies of the organization. For the system to be stable, processes and resulting products should be monitored and measured, and services about policy, objectives, and requirements. Reporting on the results is also necessary. Based on the report, measures are taken to improve

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performance, or the system remains as it is. ETV following the Law on Public Enterprises whose founding authorities of the Republic of Serbia were appointed companies. The part of the company is supervisory boards and directors. Rulebook on job systematization special organization parts are defined that is, basic organization units.

Maintaining a modern state of 24/7 global operations requires continuous network monitoring, and reliable, constant connectivity. Industries like telecommunications, but also financial services, manufacturing, and the energy sector operate around the clock (LaMoreaux, 2021). For financial institutions critical event management is vital to the continued operations, time is very important, and sometimes even seconds matter. The financial institution needs 24/7 mission-critical monitoring. Operation centers in financial institutions provide continuous insight into the threat landscape (cyber security, sensitive personal information highly valuable...). The visibility offered by NOC which is our real-time command and control means operators can quickly assess events and act quickly to keep assets out of harm's way. Today online banking is very sensitive to network failures (IT failures) and cyber-attacks.

NOC for manufacturers is also very important. NOC proactively identifies and troubleshoots network issues, because a single network glitch can halt production lines, leading to costly delays and missed deadlines. Second, modern manufacturing uses mainly Industrial IoT devices. IoT devices are being monitored from NOC to ensure they function optimally and collect critical production data. This system Implements robust security measures and ensures everyone has the information they need to make informed decisions.

NOCs in the sector of production and distribution energies were connected to energy source controllers via some network connection. The controllers are connected to the sensors in the power system and convert digital data to sensor signals and vice-versa (Elsaadany & Soliman, 2016). Cyber threats are a constant concern. For example, in December 2023 a hacker attacked the Electric Power Company of Serbia (EPS) on the internal information system. For the same reason, consumers who tried to pay or check their electricity bills, could not do so. Fortunately, the attack she organized did not stop the company’s work, at least when it came to the basic activities of Electricity production and its delivery to consumers.

The papers are organized as follows. Section 2 provides an introductory background about related works. Section 3 describes NOC from ETV along with its requirements. Chapter 4 describes the procedures used in the NOC. Chapter 5 represents the result of using equipment and procedures in an operating environment that serves the NOC concept. Finally concludes what the environment was analyzed and what results it provides.

2. RELATED WORKS

Quadranq system applies organization and management of affairs proactive monitoring. This type of monitoring allows departments to identify and resolve potential issues before they can cause any disruptions or impact the system. An all-encompassing method of managing IT systems, proactive monitoring entails actively identifying and resolving possible problems before they hurt operations or create interruptions. They are monitoring key performance indicators (KPIs), and enterprises can ensure that their system operates within optimal parameters. In this way, we have improved reliability, reduced downtime, critical business processes continue without interruption, and enhanced user experience. This proactive system monitors metrics, anomalies, and early warning signs. This solution is the best for company analysts and DevOps engineers. Our enterprise is based on the other working principle.

The network monitoring system of Dimofac has 3 main processes: process monitoring, control system, and inline quality control. This type of monitoring aims to collect process data

for different production assets and display them on screen in real-time. Operators can react immediately to pause the process and take corrective actions. The control process triggers a correction in case of deviation. With the control process, the system corrects automatically. Quality control can feed a closed-loop control of the processes and thus automatically correct process parameters. The data can after that be analysed for constant quality improvement. This solution is mainly used in the control and monitoring of factory manufacturing.

Fujitsu Network Automation application built by the Virtuora cloud and established multi-vendor ecosystem. Network automation enabled by artificial intelligence and machine learning is needed to guarantee quality of service delivery. This solution is an application that provides service management and orchestration, open network control, and data-driven network intelligence. The application includes new ways to monetize the network, also new business models, and new service offerings that are very differentiated. This solution is also not for us and is used in networks with a large number of endpoints, like a 5G+ system.

ERI network operation management is fully integrated from front to back and fully configurable. It powers seamless customer-centric workflows to deliver optimal business performance. This software solution automates complex processes while mitigating risks, controlling costs, and unlocking enterprises' full potential for innovation and growth. This solution uses mainly Large banking systems and financial institutions.

The main task of NOC PE ETV is monitoring, controlling, and correcting broadcast signals. The entire network is under control. The main part of it is the DVB-T2 signal flow by the SRPS EN302755 standard. Several subsystems are controlled by NOC. The contribution center is one of the systems that monitors coding, creating program flows, and network adapters. We are controlling the main national or regional contribution-distribution hub (Main station or Head-End) and perform functions of multiplexing, and inserting information related to the program. Through Head-End we monitored and served information, information used for the synchronization of all broadcast centers (necessary when working with cochannel networks), additional information related to audio, and video, as well as subtitles and Teletext and interactive applications. The next segment which is monitoring is the primary network or primary distribution. This network is a point-to-multipoint IP network that distributes the various services. Various services make up the digital multiplex to broadcast locations for broadcasting. The network of transmitters and gap fillers is subject to serious supervision and control. In the end is important to mention that the NOC supervises energy equipment and infrastructure (fire protection systems and camera systems).

3. HARDWARE AND SOFTWARE SUPPORT IN NOC

Hardware and software support to establish a stable work system is extremely complex. Each step to ensure a stable system is accompanied by procedures. In this chapter, we give an overview of the existing solutions for the Network operation center, their features, advantages, and disadvantages, and describe in particular the organization and functionality of the other parts of the monitoring. Equipment must be as the study shows in the next chapter that there are formal and informal procedures and incident resolution strategies applied on a case-to-case basis. (Kee et al., 2015).

The company owns a large number of facilities with equipment. Figure 1 represents the equipment and software that we use in NOC.

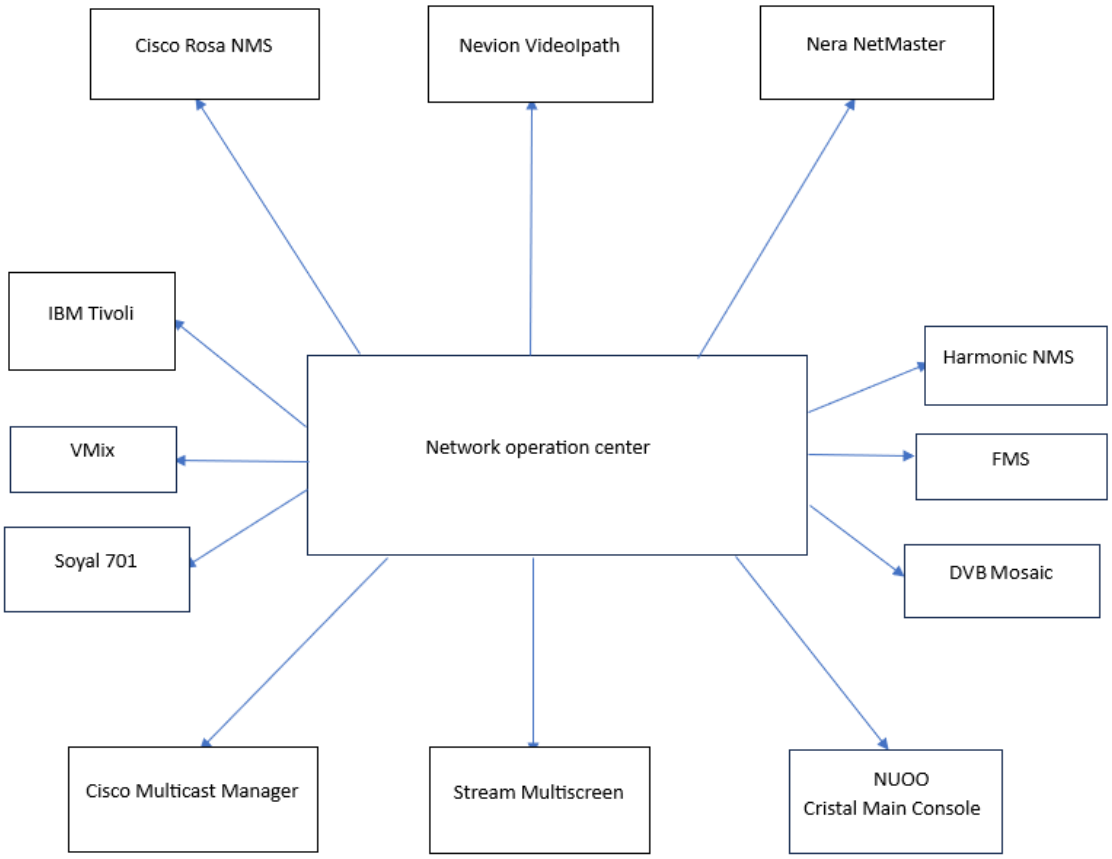

Figure 1. The modern concept of NOC

The ROSA NMS enables to configuration and control of Cisco Video Processing devices, encoders, and Digital content managers. The element manager of ROSA monitors and controls the transmission network of headends, hub sites, HFC (Hybrid Fiber-Coaxial) outside plants, and transmitter sites. VideoIPath combines network orchestration and broadcast control. This network management system is designed specifically to take full advantage of IP and IT technology in LANs, WANs, and the cloud Figure 2. Nera NetMaster is software designed for network device discovery, group configuration, auto topology, real-time monitoring, and diagnostics. It secures network devices and physical links, and a resilient network manages device configurations, fault alerts, and event logs. It ensures network reliability in large-scale networks up to 2000 nodes. We use about 40 nodes, Figure 3. In our complex system, we monitored microwave links in 4GHz and 8GHz (for special activity 5Ghz and 11GHz – short distance connections). Cisco Multicast Manager uses topology and displays routers and their multicast information in the database in two ways. The first procedure is on an individual basis, second procedure means that shows the complete database. This manager allows the use of video probes, and in this way home pages of Cisco Multicast Manager display threshold-exceeded alerts that the probes generate. Harmonic NMS allows 24/7 management of Harmonic encoders, stream processors, and components in the workflow. With this NMS defines a batch of service plans or service routing changes, and schedules in a graphical timeline view. This software is mainly used for Harmonic types of equipment and creates DVB tables and descriptors.

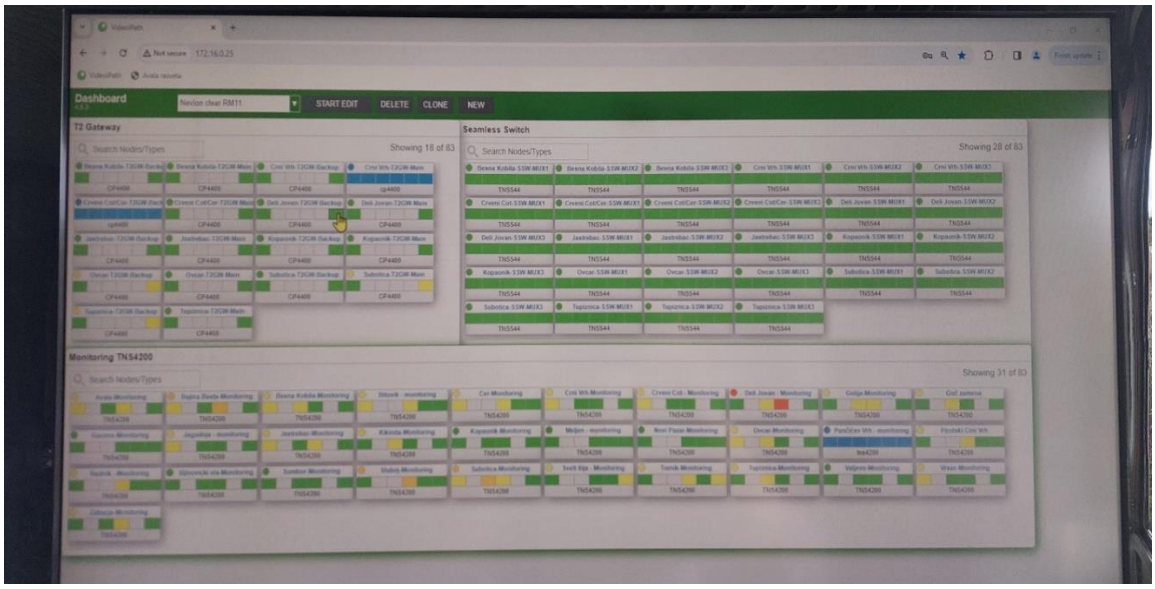

Figure 2. Nevion VideoIPath NMS

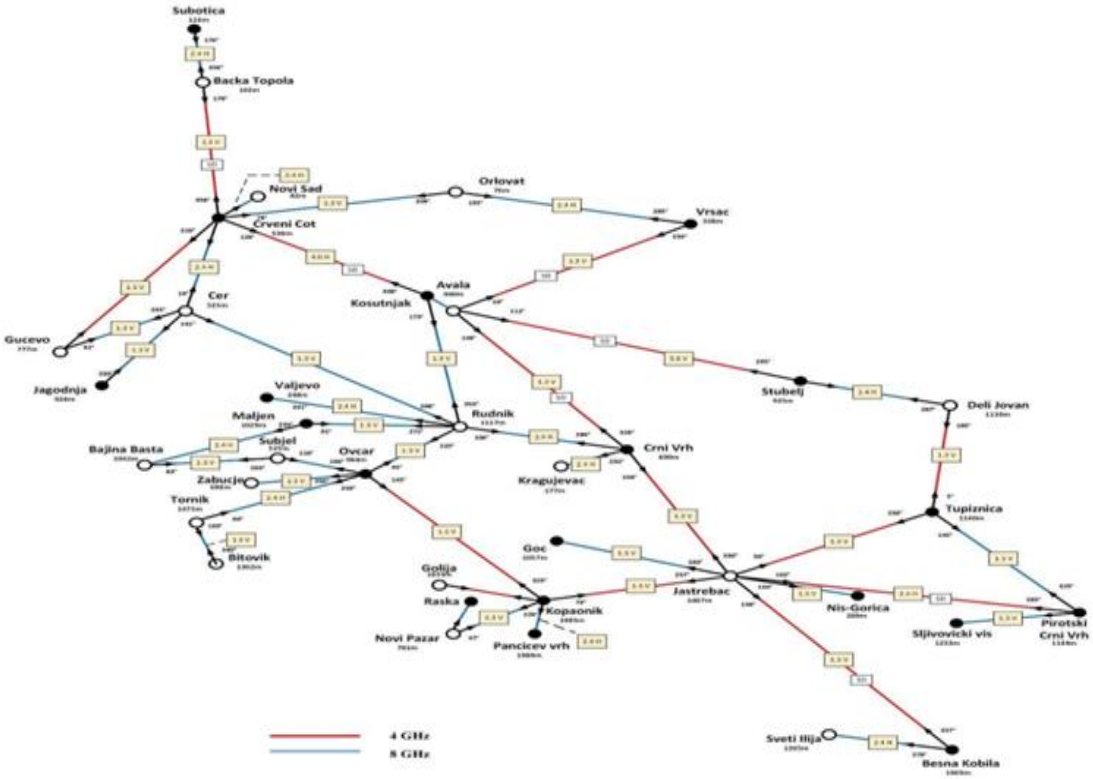

Figure 3. Software Nera NetMaster

VMix is a software that creates, mixes, switches, records, and live streams professional live production. It is very important because with this software we show new, significant service information to users (insertion of new services, cancelation of the old ones, changes in the broadcasting system…). All this is done through separate information and service channels that make it easier for users to watch and adjust the program. Stream Multiscreen system is used for Visual service presence monitoring with some distribution zones as well as centralized monitoring of the other 11 servers in remote locations. We monitored the HD (high definition) channels and a large number of SD (standard definition) channels. DVB Mosaic system is used

for visual surveillance of the presence of services in the distribution zone of interest and output from the national Head-end Figure 4.

Figure 4. DVB Mosaic system

IBM Tivoli provides lifecycle management of user accounts on remote resources. This software did with adapters and policy-based provisioning to enable access to the managed resources that an enterprise requires. This system uses a virtual appliance and centralizes the process of provisioning and accessing the operating systems in our enterprise. FMS (Fleet management solution) system provides tracking and positioning of commercial vehicles via GPS (Global Position System)/GSM (Global system for mobile communication) communication. We adopted this program to monitor power generators Figure 5. Soyal 701 software is used to monitor fire remote control panel locations as well as all sensors (motion, smoke, fire, door magnet, control access, ...). For control access, the Soyal system uses Tokens or Cards, or PIN (Personal identification number) numbers to provide users with access to doors. Each for example token has a unique user number to which they are identified during programming. Each token is provided with access rights that are defined by individual doors and individual times. NUOO Cristal's main control is used for visual control of all IP cameras at remote locations as well as recorded material. We display live video and configure the system. NUOO Cristal's main control enables many useful features such as a playback system, backup system, remote live viewer, remote playback system, remote backup system, and mobile viewer. For example, features of NUOO Cristal's main control playback system make browsing records smarter and faster through our intelligent system. The goal of this chapter is to present all the complexity of a modern telecommunication system, and that

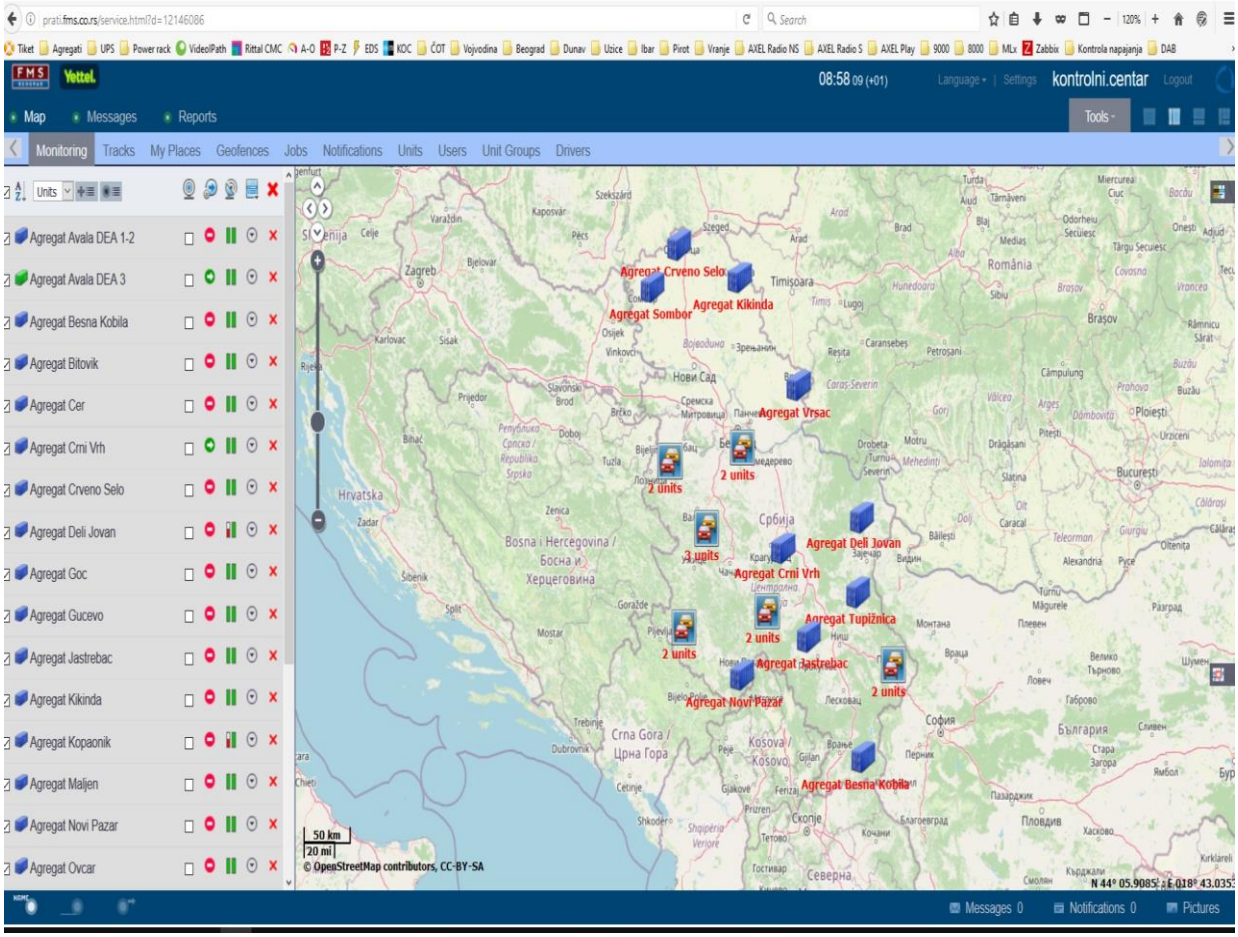

Figure 5. FMS system

without clear procedures that we apply, the system will be out of control. Procedures through documenting step-by-step instructions, procedures provide a clear guide for employees to follow, reducing the likelihood of error or variations in how tasks are completed (Ungan, 2006).

4. OPERATING ENVIRONMENT OF NOC

The objective of this chapter is to present solutions that lead to using procedures for reliable operation. The incident management procedure is essential for establishing a stable system in the shortest possible time. Procedure supervision and management through network operation center. In the event of a network incident, fault identification activities are performed, the timely response of maintenance teams, informing users, and reporting to competent services of the enterprise. Application of the procedure begins when the technician in NOC receives information. Information received by NMS, viewers, users of services, or departments broadcasting stations. Next, potentially faulty equipment is checked, then basic equipment parameters remotely and intervention. If necessary forwarding information to network maintenance services and network components, and involving a second line of support and escalation to management Figure 6.

Figure 6. Procedure supervision and management

Major incidents can occur in case of head-end failure if redundancy does not work, non-broadcasting for more than 5 minutes in the main station, natural disaster to the main broadcast station, second support line is not available. Problem analysis therefore involves identifying the problem and establishing the causes and effects related to the problem (Dul, 2016). After a deep analysis, we can fix the weaknesses in the system.

The second procedure describes priority, time of reaction, and elimination of causes and the consequences of a failure on the telecommunications network. We have several categories: elimination of the cause and consequences of the incident immediately after reception notifications, at least within 4 hours, 8 hours, and at least within 12 hours. Procedures describe the possibility sort of an incident I clearly defined the speed of intervention.

Database which creates operator in network operation center described in the third procedure – recording interruption in program broadcasting. Any incident in the network enterprise monitors an open ticket in the ticketing system. In this ticket, we have rules about the type of equipment, coverage area, who is needed for intervention, and the status of the ticket. The ticket status is clearly defined. In this way, the conditions under which the ticket is closed are precisely defined (with confirmation from the repair team, and establishment of system stability...). Then the ticket is placed in the database for later analysis and feedback that will serve to improve the performance of the entire system.

The following procedures define the conditions of collection information: areas covered by the incident in the enterprise network, type of equipment and devices included in the incident, consequences of the incident, and possible causes of equipment failure.

This procedure is followed by a fault report, reports on equipment intervention, and reports of a team on site of interest. Failure reporting via the call center is also a very important procedure for the network operation center. Managers in call centers described in the next procedure verbal communication skills, techniques of listening and asking to manage time and conversation control, skills in solving the request of viewers and users services, skills of timely creation and forwarding of notification to users of enterprise service. With the help of this knowledge, the notice contains The exact location of the incident and the distribution zone to which it relates, a clear and comprehensible description of the incident, the time of the incident, and possible duration.

5. PROFIT OF THE OF NOC ORGANISATION

The quality of the management system and its processes are in the document management review. The document management review contains besides other important information, the duration of the broadcast interruption depending on the interruption period. The cause of the interruption is classified under several separate categories. The cause of the interruption is analyzed every six months. Plans and purchases of new equipment are made based on it. The application of new technologies and improvement of the existing system is also carried out, based on the analysis from the document review. The cause of the interruption is equipment failure, announced works on equipment, electrical energy, natural disasters, and user's equipment Table 1, Table 2.

Table 1. Duration of the interruption

The cause of the interruption	Duration of interruption by month in 2022					
	July	August	September	October	November	December
Equipment failure	00:32:12	00:06:32	00:00:57	00:07:47	00:05:43	00:03:52
Regular works	00:00:03	00:00:05	00:00:04	00:09:23	00:00:11	00:00:00
Electrical energy	00:12:40	00:35:45	00:32:08	00:08:58	00:20:26	00:26:07
Natural disaster	00:00:00	00:00:00	00:00:00	00:00:00	00:00:26	00:00:00
Total duration	00:44:55	00:42:22	00:33:09	00:26:08	00:26:46	00:29:59

Table 2. Total duration of the interruption

The cause of the interruption	Total duration(s):	Participation (%):
Equipment failure	3423	28,06
Regular works	586	4.80
Electrical energy	8164	66,92
Natural disaster	26	0.21
Total duration	12199	100

Data analysis is the process of inspecting, cleansing, transforming, and modeling data to discover useful information, inform conclusions, and support decision-making (Brown, 2014). The data analysis gives us information on the weakest points of the system. The equipment at the location with interruptions and downtimes was replaced in the following quarter. In the same way, the big problem of reparation of the electric power infrastructure and the regulation of the supply voltage started from the most sensitive location.

6. CONCLUSION

In this paper, we represented NOC by the procedures and relevant equipment. We received an organized system and material for analysis. It originates from various types of reports, and tickets. Failure and intervention reports that are aligned with the procedures are daily, weekly, and monthly. They contribute to the filling of a database that is ready for analysis. Analyzes are performed according to the type of equipment, location, coverage area, condition for that time of year, and applied technologies. Based on the applied procedures in NOC and their product, we get various useful information. We improve existing technologies, with various hardware and software solutions, or if it is necessary to switch to new technologies. Sometimes we use the new technology and the existing one at the same time, giving time for clients and users to adapt to the new one. Through the procedures in the NOC, the clients and users were notified electronically (via e-mail) and by phone. There is also an info channel edited by the NOC. In that info channel is a timeline of planned new technologies, and changes in the broadcasting system. Employees at NOC themselves press others in the chain of cooperation to apply procedures, because they bring them safety at work, and reduce the possibility of mistakes in a complex environment. Every change in the NOC work system is accompanied by a change in the corresponding procedure, every change in the application of technology also implies adaptation of the existing procedure. The procedures bring security in work to the NOC operators, and solve the unknown of which way to go to complete the work successfully. Continuous monitoring of the system works through procedures and ensuring its continuity functioning, with the ultimate goal of raising the level of user and viewer satisfaction by timely intervention during incidents and errors in the enterprise network.

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