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In front of the publisher: Prof. dr Dejan Tanikić*, Dean of Technical Faculty in Bor
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ENTERPRISE RISK MANAGEMENT USING THE FMEA-AHP APPROACH

Marija Panić *

University of Belgrade, Technical Faculty in Bor, Serbia

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

* *Corresponding author: mpanic@tfbor.bg.ac.rs*

Marija Panić, ORCID: 0000-0001-7287-758X

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.

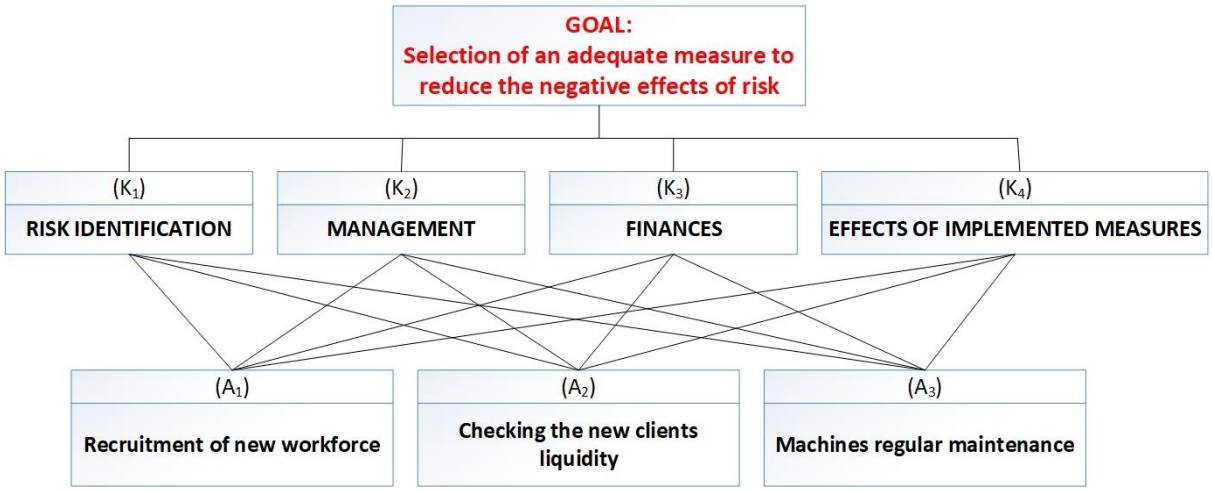

Figure 1. A schematic representation of the defined AHP decision model

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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