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A TOOL FOR RISK ASSESSMENT

Abstract: *A lot of companies need to carry out a risk assessment, but most of them do not have the experience to determine the risk in a qualitative way. Therefore, these organizations use the tools for qualitative or qualitative - quantitative risk assessment. A useful tool for risk assessment is risk matrices (risk assessment scoring matrices/ risk ranking matrices).*

The aim of this paper is to present various risk matrices. Typical risk assessment matrices with different levels recommended by the American standards and other standards have also been presented in this paper.

Key words: reliability, severity, risk, matrix, probavility.

INTRODUCTION

Risk can be the subject of discussion if there are at least two outcomes of an event (occurrence) or in case if there is at least one outcome that is not desirable. The fact that there are more outcomes of an event causes indeterminedness while the fact that the outcome of an observed event may be different from the desired, creates the possibility of loss [12].

The term anticipated value at risk is used to link the probability and the loss. Value at risk is a widely used risk measure of the risk of loss (consequences of the risk occurrence). In practice, the term risk is often used to denote the value at risk [12].

Risk is a concept that denotes a potential negative impact on some of the characteristics of values that can arise from a future event, or in other words, risks are events or conditions that may occur, and their occurrence can have dangerous or negative effects. Risk is incurred by the exposure to the consequences of uncertainty.

Qualitatively, risk is proportional to the expected losses that can be induced by a certain accident and to the likelihood of an occurrence. Greater loss and greater likelihood result in an increased overall risk.

In engineering, the definition of risk is:

RISK = (Probability of Accident) x (Losses per Accident).

Risk management can be defined as a general management function with the aim to identify risks, assess risks and prepare the organization (company) how to best handle the effects (consequences) of the risks. [1]

The purpose of risk management is to enable organizations to realize their goals in the most direct, effective and efficient way. Risk management applies to all risks. The aim of risk management is to reduce the existing risks to the levels acceptable by the society.

Risk assessment is the first general step in risk management. Risk assessment is determination of quantitative or qualitative value of risk related to a concrete situation and a recognized threat. Quantitative risk assessment requires calculations of two components of risk R, magnitude of the potential loss L, and the probability p that the loss will occur.

RISK MATRICES

Risk ranking is based on a matrix whose axes are the ranks of consequences and probability. The combination of ranks of consequence and likelihood creates risk rank. Although many risk matrices have already been developed and implemented, the development of new risk assessment matrices is a special challenge.

Characteristics of Risk Matrices

Although risk matrices are easy to use, they can create liability issues and give a false sense of security.

An effective risk ranking matrix should have the following features [11]:

- Be simple to use and understand
- Not require extensive knowledge of the use of quantitative risk analysis
- Have clear orientation to applicability
- Have consistent likelihood ranges that cover the full spectrum of potential scenarios
- Have detailed descriptions of the consequences that relate to each consequences range
- Have clearly defined tolerable and intolerable risk level
- Show how a scenarios that are at an intolerable risk level can be mitigated to a tolerance level on the matrix
- Provide a clear guidance on what action is necessary in order to mitigate the scenarios with intolerable risk levels.

Typical risk assessment matrices

There are two ways to evaluate the matrices of consequences and likelihood: qualitative and quantitative. Therefore, there are two types of matrices: qualitative and quantitative- qualitative. The first type is used for qualitative assessment of likelihood and consequences, while the second type is used for quantitative assessment of likelihood and qualitative assessment of consequences.

Both matrices classify the consequences by using the following terms: death, major permanent disability, minor permanent disability, temporary disability.

In qualitative matrix, likelihood is represented through the following categories: frequent, likely (probable), accidental, unlikely, improbable.

Likelihood in quantitative-qualitative matrix is expressed quantitatively, as follows: 100-999/10000, 10-99/10000, 1.0-9.9/10000, 0.10-0.99/10000, 0.010-0.099/10000.

Typical risk assessment matrices are the following: the matrix derived from the U.S. Military Standard MIL-STD-882c which has 6 categories of likelihood and 4 categories of consequences; a 5x4 matrix derived from the U.S. Military Standard MIL-STD-882B; a 3x3 matrix with 3 levels of risk according to OHSAS standard, recommended by the European Agency for Occupational Safety and Health; a matrix according to Australian standard AS/NZS 4360: 2004.; a 5x5 matrix with 4 levels of risk: law, medium, increased, extreme; a 4x4 risk assessment matrix by NCPS (U.S. Department of Veterans Affairs National Center for Patient Safety); a 5x3 matrix designed according to the Regulation on Chemical Risk and Environment Pollution Assessment, Preparation. Measures and Remediation Measures (Official Gazette of RS No. 60/94, 63/94).

Qualitative matrix is presented in Table 1, whereas qualitative-quantitative matrix is presented in Table 2.

Table 1. *Qualitative matrix for risk assessment [3]*

Likelihood	**Consequences**			
	Death	Major permanent disability	Minor permanent disability	Temporary disability
Frequent	1	3	7	13
Likely	2	5	9	16
Accidental	4	6	11	18
Unlikely	8	10	14	19
Improbable	12	15	17	20

Table 2. *Quantitative- qualitative matrix for risk assessment [3]*

Likelihood	**Consequences**			
	Death	Major permanent disability	Minor permanent disability	Temporary disability
100-999/10000	1	3	7	13
10-99/10000	2	5	9	16
1.0-9.9/10000	4	6	11	18
0.10-0.99/10000	8	10	14	19
0.010-0.099/10000	12	15	17	20

Risk ranking: 1-5: unacceptable risk - must be reduced, 6-9: undesirable risk - all feasible measures must be applied, 10-17: acceptable risk, 18.20: acceptable risk

The simplest matrix is 2x2 matrix presented in the figure 1.

Probability		Consequences	
		Major	Minor
	High	**1**	**2**
	Low	**2**	**3**

Figure 1. *Risk assessment matrix [6]*

Probability: high - expected to occur in the following 12 months; low - is not expected to occur in the following 12 months

Risk:

1 - high risk; 2 - medium risk; 3 - low risk.

Typical risk assessment matrix recommended by The U.S. Department of Defense Standard Practice for System Safety (MIL–STD–882) is shown in figure 2.

Severity	Probability					
	F Impossible	E Improbable	D Remote	C Occasional	B Probable	A Frequent
I Catastrophic						
II Critical						
III Marginal						
IV Negligible						

Figure 2. *Risk assessment matrix according to MIL-STD-882C[5]*

High risk
Medium risk
Small risk

Increased risk
Severe risk
Medium risk
Low risk

The U.S. Department of Defense uses 5x4 risk matrix (MIL-STD-882B) shown in Figure 3.

PROBABILITY	**SEVERITY**			
	I Catastrophic	II Critical	III Marginal	IV Negligible
A) Frequent	**1**	**3**	**7**	**13**
B) Probable	**2**	**5**	**9**	**16**
C) Occasional	**4**	**6**	**11**	**18**
D) Remote	**8**	**10**	**14**	**19**
E) Improbable	**12**	**15**	**17**	**20**

Figure 3. *Risk assessment matrix according to MIL STD 882B [2]*

Severity	**Category**	**Definition**
Catastrophic	I	Death or system loss
Critical	II	Severe injury, occupational illness, major system damage
Marginal	III	Minor injury, minor occupational illness, minor system damage
Negligible	IV	Less then minor injury, occupational illness, or systemm loss
Probability	**Level**	**Definition**
Frequent	A	Likely to occur frequently
Probable	B	Will occur several times in the life of an item
Occasional	C	Likely to occur sometime in the life of an item
Remote	D	Unlikely, but possible to occur
Improbable	E	So unlikely, it can be assumed occurrence may not be experienced

Figure 4 shows the risk matrix according to the Australian standard AS/NZS 4360: 2004. A 5x5 risk matrix with 4 risk levels: extreme risk, high risk, medium risk and low risk, whereas

E – Extreme risk – detalled action plan required
H – High risk – needs senior management attention
M– Medium risk – specify management responsibility
L – Low risk – manage by routine procedures

Extreme and high risk demand more detailed plan to reduce risk to medium or law risk.

					Potential consequence				
				People	Injuries and diseases that do not require medical treatment	Minor injuries that require first-aid only	Severe injuries that require hospitalization or multiple medical treatment	Life-threatening injuries or multiple injuries that require hospitalization	Death or multiple injuries that pose threat to life
				Reputation	Internal control	Observation by internal controls to prevent escalation	Observing that require external executors or investigation	Intense public or political significance	Publicity
				Business process and systems	Minor errors within the systems or processes that require corrective action	Failure to procedures in the process	The requirements for one or more responsibilities are not met	Strategies are not in accordance with the national plan	Critical system failure, bad policy advisory
				Finance	1 % of budget	2.5 % of budget	> 5 % of budget	> 10 % of budget	> 25 % of budget
					Insignificant	Minor	Moderate	Major	Catastrophic
	Probability	Historical			1	2	3	4	5
Likelihood	>1in 10	Is expected to occur in most circumstances	5	Almost certain	M	H	H	E	E
	1 in 10 – 100	Will probably occur	4	Likely	M	M	H	H	E
	1 in 100 – 1000	Might occur at some time in the future	3	Possible	L	M	M	H	E
	1 in 1000 – 10000	Colg occur but doybtful	2	Unlikely	L	M	M	H	H
	1 in 10000 - 100000	May occur but only in exceptional circumstances	1	Rare	L	L	M	H	H

Figure 4. *Risk assessment matrix according to Australian and New Zealand risk management standard AS/NZS 4360: 2004[23]*

Recommendations for OHSAS standard by the European Occupational Health and Safety Agency recommned a 3x3 matrix with 3 risk levels (low, medium and high), as shown in Figure 5.

Likelihood	Consequences		
	Slightly harmful	Harmful	Extremely harmful
Highly unlikely	**Low**	**Low**	**Medium**
Unlikely	**Low**	**Medium**	**High**
Likely	**Medium**	**High**	**High**

Figure 5. *Risk matrix [4]*

Likelihood:

Highly unlikely - will not occur during the whole professional career of an employee

Unlikely - may occur more than once during the whole professional career of an employee

Likely - could occur several times during the whole professional career of an employee

Consequences:

Slightly harmful - accidents and illnesses that do not cause long-term effects (minor injuries, eye irritation, headaches, etc.).

Harmful - accidents and illnesses caused by secondary, but no long-term consequences (fractures, second-degree burns on a limited body surface, allergies, etc.).

Extremely harmful - accidents and illnesses that cause serious and permanent consequences and/or death (amputations, complex fractures leading to disability, cancer, second and third-degree burns, burns over a large body area, etc.).

High risk is unnacceptable

Low and medium risks are acceptable

4x4 Risk assessment matrix by NCPS (US Department of Veterans Affairs National Centre for Patient Safety) is shown on figure 6.

		Severity			
		Catastrophic	Major	Moderate	Minor
Probability	Frequent	**3**	**3**	**2**	**1**
	Occasional	**3**	**2**	**1**	**1**
	Uncommon	**3**	**2**	**1**	**1**
	Remote	**3**	**2**	**1**	**1**

Figure 6. *Risk assessment matrix [21]*

Probability: in order to rank probability, it is important to know how often a concrete event happens.

- Frequent – can occur several times in a year,
- Occasional – can occur several times in 1 or 2 years,
- Uncommon – can occur several times in 2 or 5 years,
- Remote – can occur once in 5 or 30 years.

Severity:

- Catastrophic – death or serious bodily injuries,
- Major – permanent loss of body functions,
- Moderate – minor bodily injuries

Risk:

1 - Low risk,
2 - Medium risk,
3 - High risk.

Figure 7 shows 8x6 risk matrix.

Likelihood		Consequences			
		Very serious	Serious	Moderate	Minor
Almost certain	> 50 %	**S**	**S**	**S**	**M**
Very likely	> 1/10	**S**	**S**	**S**	**L**
Rare but likely	> 1/100	**S**	**S**	**S**	**L**
Slightly	> 1/1000	**S**	**S**	**M**	**A**
Likely	> 1/10000	**S**	**M**	**L**	**A**
Almost unlikely	> 1/100000	**M**	**L**	**A**	**A**
Unlikely if not intentional	> 1/1000000	**L**	**A**	**A**	**A**
Unlikely	< 1/1000000	**A**	**A**	**A**	**A**

Figure 7. *Risk assessment matrix [17]*

Figure 8 shows 5x3 matrix according to Rules on the methodology for assessing the risk of chemical accidents and environmental pollution, preparatory measures and measures for the elimination of consequences ("Official Gazette of RS", no. 60/94 and 63/94)

		Consequences				
		Negligible	Minor	Serious	Major	Catastrophic
Likelihood of accident	Low	**Negligible risk**	**Minor risk**	**Serious risk**	**Major risk**	**Catastrophic risk**
	Medium	**Minor risk**	**Serious risk**	**Major risk**	**Catastrophic risk**	**Catastrophic risk**
	High	**Serious risk**	**Major risk**	**Catastrophic risk**	**Catastrophic risk**	**Catastrophic risk**

Figure 8. *Risk assessment matrix [8]*

Risk assessment of consequences can be done on the basis of the indicators in the following table:

		Consequences				
		Negligible	Minor	Serious	Major	Catastrophic
Indicators that determine the consequences	Number of dead	-	-	1-5	6-20	>20
	Number of injured - intoxicated	-	1-10	11-50	51-200	>200
	Dead wild animals	< 0,1t	0,1-1t	1-2t	2-10t	>10t
	Dead domestic animals	< 0,5t	0,5-10t	10-50t	50-500t	>500t
	Dead fish	< 0,5t	0,5-5t	5-20t	20-100t	>100t
	Contaminated area	-	1-10ha	10-100ha	1-5km^2	>5km^2
	Damage of shares	< 0,02 million dinars	0,002-0,2 million dinars	0,2-2 million dinars	2-10 million dinars	>10 million dinars

Advantages and disadvantages of risk assessment matrix

Risk assessment matrix has the following advantages:

1. It is a useful guide for engineering practice.
2. It is a standard tool for establishing the connection between consequences and probabilities in risk assessment of a given exposure to risk.
3. It disables the acceptance of unnaceptable risk and enables making operating decisions, improving the distribution of resources to mitigate the loss.

Limitations of the risk assessment matrix are:

1. The possibility of applying only identified hazards (not a tool for the identification of hazards).
2. Subjectivity.
3. The possibility of a comparative risk analysis only.

RISK ASSESSMENT METHODS

The EU Directive stipulates that each country can adapt a risk assessment methodology suitable to its legislation. Some EU member states have specific regulations on the manner and methodology for risk assessment.

Risk assessment matrices are used in various methods for risk assessment. Depending on the data and the matrix used, the methods can be: qualitative, quantitative and qualitative -quantitative.

Some of the typical methods for occupational risk assessment are: the AUVA method-the method of Austrian group of paper and pulp producers (Allgemeine Unfallversicherungsanstalt) and WKO method (Wirtschaftskammern Österreichs)-the Austrian Federal Economic Chamber; BG (Die genjerblichen Berufsgenossenschaften)- method of German professional associations; SME - Safety and Health method for Small and Medium sized Enterprises recommended by the EU. A special method defined by the Regulation on risk assessment is used in Croatia [7].

CONCLUSION

After defining a risk assessment matrix, diagrams of risk and the process and rules of transformation of a risk diagram into a risk matrix, and presentation of the matrix for risk assessment according to various standards (U.S. Military Standard MIL STD 882, Australian Standard AS / NZS 4360: 200, OHSAS standards and others) it can be concluded that it is best to choose matrices with fewer categories of likelihood and consequences, and smaller number of risk ranks. Accordingly, the most common types of matrices are 3x3, 4x4, 5x5, 5x4 and 6x4.

In the case of matrices with fewer categories of likelihood and consequences, it is easier to choose the level of consequences and likelihood that corresponds to the factual situation.

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BIOGRAPHY

Dejan Ristić was born in Zemun, Serbia, in 1975. He received the diploma in fire protection and master degree in safety at work from the University of Nis, Faculty of occupational safety in Nis.
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ALAT ZA PROCENU RIZIKA

Dejan Ristić

Apstrakt: *Mnoge organizacije imaju potrebu za procenom rizika, ali većina ne poseduje iskustvo i resurse da rizik kvantitativno odredi. Zbog toga, ove organizacije koriste alate za kvalitativnu ili kvalitativno-kvantitativnu procenu rizika. Koristan alat za procenu rizika su i matrice rizika (matrice za rangiranje rizika).*
Cilj rada je da se prikažu različiti tipovi matrica za procenu rizika. Tipične matrice za procenu rizika sa različitim nivoima koje proporučuju američki standardi, kao i drugi standardi, prikazane su u ovom radu.

Ključne reči: pouzdanost, ozbiljnost, rizik, matrice, verovatnoća.