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APPLICATION OF THE MATRIX APPROACH IN RISK ASSESSMENT[1]

Nenad Kovačević[a*], Aleksandra Stojiljković[b], Mitar Kovač[c]

[a] University of Defence, Military Academy, Belgrade, Serbia
[b] University of Novi Sad, Faculty of Economics, Subotica, Serbia
[c] "Educons" University, Faculty for Project and Innovation Management, Belgrade, Serbia

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Abstract. *The risk assessment process is based on risk management. Risk assessment is, in principle, an entirely empirical decision-making process, based on risk assessors' knowledge and experience, necessary to identify (a) hazard(s) as the cause for risk by using specific and well-known and recognized methods so far. Currently, there are a large number of methods recognized for risk assessment, which are mostly formed by various organizations and associations of engineers, usually in insurance companies. The paper presents the most pragmatic matrix (qualitative) risk assessment methods, such as: a 3x3 matrix (OHSAS), a 4x4 matrix (AS/NZS 4360) and a 5x5 matrix (MIL-STD-882B). The paper is significant in that the matrix approach in risk assessment is the basis for the development of risk assessment methods, regardless of the method of the group which they belong to.*

Key words: *decision-making, risk assessment, matrix approach*

1. Introduction

One of the main characteristics of the modern era is the permanence of change in all spheres of life and work. A science ratio and the frequency of change are in a causal relationship, given the fact that science (especially the field of technical-technological sciences) is usually the cause of changes, as well as the sphere of the

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* Corresponding author.
inz.84kula@gmail.com (N. Kovačević), aleksandra.stoiljkovic@yahoo.com (A. Stoiljkovic), mitar.kovac21@gmail.com (M. Kovač)

human action, which is permeated by the repercussions reflections of the same. However, as part of planning (the initial process functions of management), decision-making is also present in the other functions (organization, coordination and control). Risk management and decision-making are inextricably linked to each other, because there is no decision without a certain level of risk. Consequently, risk management is the state of the process or a set of environmental conditions which can be treated adequately and comprehensively in order to make timely, accurate and correct decisions.

Risk assessment is the basis of risk management. It is, however, important to point out the fact that, although purely empirical, risk assessment is simultaneously also a subjective process (which depends on the knowledge of the stages of the work process by the risk assessor); if, however, certain algorithms, tools and principles are followed and applied, that subjectivity may yet be reduced to the lowest possible level.

In this paper, a group of risk assessment methods (one approach), namely the matrix risk ones, are presented. The characteristic features of this group of risk assessment matrix method in general are that they (a) are developed the first, (b) are the starting point for the other groups of methods, and (c) in practice, have proven to be most susceptible to all participants of the risk assessment process.

2. Decision-Making in Terms of Risk

The very issue of decision-making as a process of coming to a decision is highly interdisciplinary and can be studied from different aspects. Business environments and organizations constantly change, so the future consequences of decisions are impossible to fully predict. In a turbulent, dynamic, uncertain and changing environment, the decision-making process becomes increasingly complex and demanding, and to make informed decisions requires a certain extensive preparation. In this regard, in an effort to comprehensively examine this problem, scientists are faced with the fact that there is poor knowledge of classical economic/financial theory included in a number of other scientific disciplines (Kolev *et al.* 2015).

Decision-making theory is a result of the joint efforts of experts in the fields of economics, psychology, philosophy, mathematics and statistics (Damjanovic & Jankovic, 2014). The theory of creating a set of knowledges and appropriate analytical techniques with different degrees of formality is designed to help the decision-maker to choose alternatives based on implications (Miskovic, 2016). It is necessary to make a distinction between the normative and descriptive (behavioral) decision theory.

Normative decision theory deals with the way in which decisions need to be made. The best decision is always sought, it being implied that the ideal decision-maker (DM) is fully informed and rational (Miskovic, 2016). Normative theory deals with the concept of the rationality and logic of decision-making as they should actually be (Milicevic et al. 2007). In the normative approach, the decision-making problem is well defined – -the principles of normative theory showing how a perfectly rational individual should make decisions. This approach assumes certain rules that people, if abiding by them, may rely on in a situation when they have to make the best decision (Damjanovic & Jankovic, 2014).

Descriptive theory describes how decisions are actually made and discusses the practical application of normative theory. The primary objective of descriptive theory is to help understand and explain how individuals consider available information and, based on such information, come to a certain decision or make a certain choice. Descriptive decision-making theory is concerned with what is singled out in normative theory as a deviation from criteria for rational behavior. The focus of interest consists of both the characteristics and the limitations of the DM's cognitive system, on the one hand, and other psychological causes for the mistakes that he makes when making a decision. Descriptive theories are focused on finding tools, methods and software to help make better decisions (Miskovic, 2016).

In theory and practice, one can find different approaches to decision-making. The access to decision-making that is increasingly gaining in importance is decision-making based on risk assessment. The term 'risks' can be associated with the uncertainty of those future events that may affect the outcome of the reporting process (Crnjac & Masle, 2013). In general, there are three different conditions in which decisions are made, and which are based on the degree of the predictability of the outcome of a future decision. In terms of security, decision-making implies that the choice of one among the alternatives based on the outcome of having chosen the alternative the most appropriate for the organization should also depend on the known outcome (result) of each alternative. However, there are situations when it is impossible for the DM to know with certainty what will happen in the future; on their own part, alternative outcomes depend on the circumstances often unknown to us. In such cases, we speak about decision-making under uncertainty and risk conditions (detectable uncertainty). In conditions of uncertainty, it is possible to determine future events, i.e. different outcomes of each alternative are possible to predict, but probability distributions are unknown, whereas in conditions of risk, each alternative has one of several possible consequences, and the likelihood of the occurrence of each such consequence is known (Damjanovic & Jankovic, 2014).

Given the variability of both organizations, as well as the environment in which they exist, future implications of decisions cannot be fully predicted. Most decisions made in organizations contain a certain amount of risk. The condition of risk(s) is actually a wide range and, inside it, the degrees of risk may be associated with decisions, in the sense that the lower the quality of information on the outcome of the alternative, the closer the situation is to complete uncertainty, for which reason the risk of selecting that particular alternative is higher (Certo & Certo, 2008). Management seeks to know the size and nature of the risks associated with the adoption of economic decisions in a particular situation. In most cases, risk analysis is based on economic analysis and estimates of probability (Kolev et al. 2015).

3. Risk Assessment Procedure

In order to understand risk assessment and its applicability, it is necessary to make a clear distinction between the concepts of governance and risk assessment. The importance of the above-mentioned is also reflected in the fact that this issue is regulated by a set of internationally recognized documents, such as the ISO 31000:2015 (Risk Management) standard. As a potential, principled, yet non-binding framework for risk management, the mentioned standard uses the PDCA

(the acronym for: Plan, Do, Check, Act) cycle, the elements of which are shown in Table 1; it is possible to notice that the first step, as well as the basis for risk management, is the identification and valorization of risks.

According to ISO 31000:2015, risk management is a more general concept in relation to estimation (assessment) i.e. risk management is based on estimation, also including the following: (1) the context establishment and (2) risk actions, i.e. risk treatment. Risk assessment itself (evaluation)consists of:

- ✓ risk identification,
- ✓ risk analysis, and
- ✓ risk evaluation.

Table 1. The PDCA cycle according to ISO 31000:2015

PDCA CYCLE	FRAMEWORK ELEMENTS
Plan	Context determination Risk assessment Risk Treatment Plan Residual risk acceptance
Do	Plan implementation
Check	Continuous monitoring and inspection (surveillance)
Act	Risk management maintenance and improvement

Source: www.risk assessment matrix.com

Risk identification is carried out in order to form: (1) a list of risk sources, (2) a list of risk causes, (3) a list of the events that may affect the achievement of the objectives defined in the context of risk management, and (4) the development of a scenario of the events. Accordingly, the standard SRPS A.L2.003 – Risk Assessment to Protect Persons, Property and Operations provides for the following types of risk: (a) risks within general business; (b) risks to occupational safety and health and safety and health in the work environment; (c) the risk of natural disasters or other disasters; (d) legal risks; (e) risks from the illegal operation of risks; (f) the risk of fire, and (g) risks of non-compliance with standards. Through risk identification, the following techniques are commonly used: (1) survey, (2) interviewing, (3) the control list (checklist), (4) the tracking- and experience-based judgments (5) scenario analysis and (6) the analysis of engineering system techniques.

Risk analysis is an input element to: (a) risk evaluation and (b) a decision on whether it should be treated with risks. The risk analysis procedure includes the following activities: (1) a description of the identified risks; (2) grouping related risk sources and risks; (3) the analysis of the influence of individual causes of risk; (4) the evaluation of the likelihood and the result of implementation risk; (5) the evaluation and quantification of risk valorization; (6) the identification of the factors that influence the effects and the likelihood; (7) a list of priority risks; (8) proposing a method/option for risk treatment and (9) defining measures for risk monitoring.

Accordingly, risk assessment is the most important part of risk evaluation (estimation being additional) because a valued risk is the product of risk analysis;

consequently, all methods are based on the risk analysis developed for the purpose of valorizing risk. The methods used in risk assessment can be divided into three major groups: (1) qualitative, (2) semi-quantitative (or a combination of the qualitative and quantitative) and (3) quantitative.

Qualitative and semi-quantitative risk analysis techniques and methods include: (a) polling; (b) the SWOT analysis; (v) causal diagrams; (c) the methods of expert marks; (d) the Delphi method; (e) a preliminary analysis of a danger; (f) the fault tree/fault/failure method, (g) the event tree method and (h) the result of the probability matrix. The quantitative risk analysis techniques and methods are as follows: (a) probability theory; (b) mathematical statistics; (c) operational research; (d) sensitivity analysis; (e) scenario methods; (f) the error log method; (g) the event tree method; (h) the Monte Carlo method, and (i) the modeling and simulation method. In this paper, considers the probability and consequence matrix or the matrix methods for risk ranking/assessment are considered as actually the basis for all the aforementioned qualitative risk assessment methods (Kovacevic et al. 2019).

Risk evaluation involves a comparison of the level of the risk detected in the risk analysis process, the risk criteria defined in the risk management context determination process, the determination of risk significance and dealing with risk. If the estimated risk meets the established criteria, that is considered as acceptable and does not require additional any control options. Otherwise, it is necessary to establish a list of priority risks and the ways to deal with these risks. Value at risk is regulated by specific standards and ISO-IEC 31010, which provides specific instructions on risk assessment techniques.

In order to answer the question how risk assessment should be performed and what the steps or procedures for risk assessment performance are, the following must first be defined:

- ✓ the risk assessment performance methodology, and
- ✓ the risk assessment performance procedure.

The risk assessment performance methodology defines the algorithm of and the tools for the implementation of and a concrete way to implement the risk assessment process, whereas the risk assessment process implementation procedure defines standardized series of steps necessary in order to ensure the process implementation in accordance with the recommendations of the relevant laws, regulations and best practice (Nikolic & Gavanski, 2010).

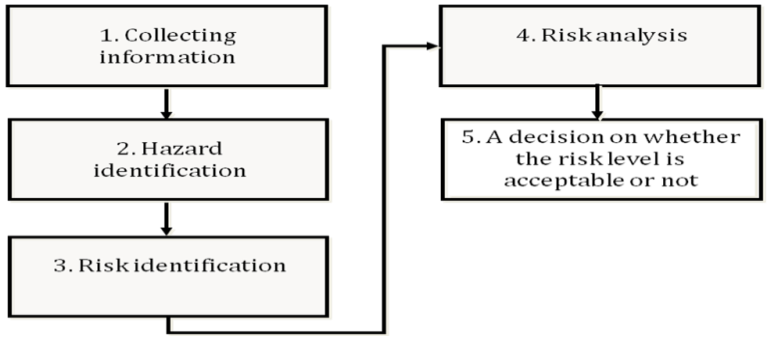

Figure 1. The steps of the risk assessment methodology

In the modern literature, the method published in risk assessment guidelines and manuals by the European Agency for Safety and Health at Work is usually used as the baseline risk assessment methodology. Based on the experience of the author of the *Risk Assessment* paper, Figure 1 is a schematic presentation of the steps of the risk assessment methodology.

4. Risk Assessment Qualitative Methods

Risk assessment qualitative methods are primarily based on the risk assessment team participants' (risk assessors') personal experiences and judgments and/or the use of available qualitative data. This approach does not require information about prior threats, hazards, causes and effects, but it does cause the end result of the risk assessment to be a descriptive statement of the qualitative risk size (e.g. high risk, moderate risk, etc.).

Qualitative criteria use the words such as: "rarely", "amazing", "possible", "probable" or "almost certain" in order to describe the probability of unwanted events, as well as the words like "fatal", "serious", "small", or "negligible" in order to describe the size of a damage-consequence. Risk assessment qualitative methods most commonly use the subjective criteria that are measured by qualitative scales. Consequently, risk assessment is subjective in nature, and therefore is subject to an error. In practice, qualitative scales with three to seven qualitative descriptions are optimally used, which requires a pronounced professional approach to potential threats and/or hazards analysis. The methods with fewer than three qualitative descriptions of risk factors are very simple, whereas if methods have more than seven such descriptions, that may lead to significant difficulties which are subjective in character associated with the inability of the risk assessment team participants to relatively precisely identify the qualitative description of risk factors/ constituents.

The best-known representatives of this group of risk assessment methods are the **matrix risk** or the **matrix risk rating**. These methods are actually the essential methods also belonging in the group of both semi-quantitative and quantitative methods. Risk assessors are often used in a risk matrix operation for the purpose of establishing a logical connection between the result and the probability of the risk assessment of identified hazards/harmfulness. Also, they are used as defined by the uniform method for the determination of the degree or level of individual estimated risks.

A risk matrix is formed through the following three steps: ranks of ordinates are applied to the probability (Step 1), and abscissas are applied to the result of the ranks/severity (Step 2). A combination of the above ranking levels results in the ranking of risks (Step 3), as is shown in Figure 2. In order to reach these data (probability and consequences), it is necessary to collect information, which is the first step in all risk assessment methods. Practical experience has shown that "checklists" are an ideal tool for collecting information useful for the identification of dangers/hazards in the workplace and the working environment. To obtain a comprehensive picture of all potential risks and hazards, and consequently a better risk assessment, it is necessary to examine all the participants (administrative and executive bodies and end-users/workers) in the work process.

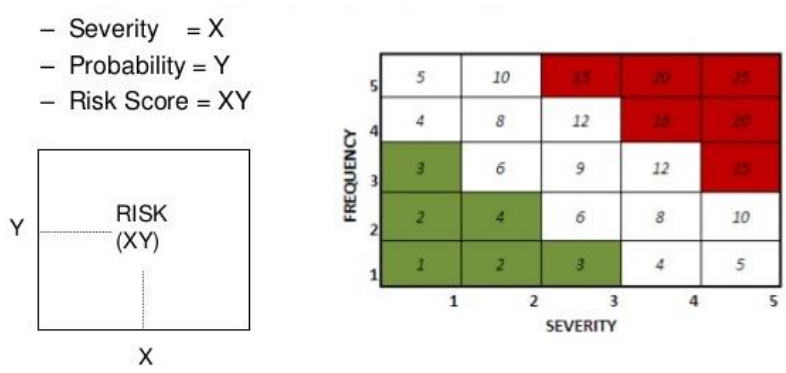

Figure 2. Forming a risk matrix (www.risk assessment matrix.com)

n practice, the following three types of the matrix risk rating are used most frequently: (1) a 3x3 risk matrix (OHSAS), (2) a 5x5 risk matrix (MIL-STD-882B), and (3) a 4x4 risk matrix (AS/NZS 4360 2004). In its Guidance on Risk Assessment, the European Agency for Safety and Health at Work recommends a 3x3 matrix, which was first defined in the standard OHSAS 18001 and which is shown in Figure 3. The matrix has three levels for the qualitative description of probability (bit-amazing, medium-probably; high-very likely), as well as consequences (minor, major and serious). Risk is also ascribed three levels, marked as a qualitative description of: low, moderate, and high. In the contemporary literature, this method is often called the "Singaporean method/model", which is but a variation of the above-mentioned methods (Kovacevic *et al*. 2017).

		Result of a dangerous event		
		Minor (1)	Moderate (2)	Serious (3)
Probability of a dangerous event	Rare (1)	*Low risk (1)*	*Low risk (2)*	*Moderate risk (4)*
	Possible (2)	*Low risk (2)*	*Moderate risk (4)*	*High risk (6)*
	Almost certain (3)	*Moderate risk (3)*	*High risk (6)*	*High risk (9)*

Figure 3. Risk matrix 3x3

The 4x4 risk matrix (AS/NZS 4360) was formed according to the standards of Australia and New Zealand and belongs to the standard ISO 31000, which relates to the risk management field. First, it appeared in 1995, and the last variation of this type of the risk ranking matrix appeared in 2009. The matrix is shown in Figure 4.

The categorization of the probability of the 4x4 risk matrix according to the recommendations of the standard A/NZS 4360 is as follows: (1) *highly unlikely* (- -) may occur, but it will probably never be the case; (2) *unlikely* (-) may occur very rarely, and (3) *is likely to* (+) may occur at times; (4) *very likely* (++) may occur at any moment, i.e. its occurrence is almost certain. The categorization of the results of a dangerous event for the 4x4 risk matrix according to the recommendations of the

standard AS /NZS 4360 is as follows: (1) *small*, (I) only the most basic first-aid measures; (2) *moderate*, (II) a medical treatment is needed; a few days of a sick-leave; (3) *serious*, (III) a serious injury, or a long-term disease; (4) *disastrous*, (IV) death and permanent damage and a permanent disability to work. Risk is categorized into six levels, the "S" level being a top priority, and an unacceptably high-risk category according to the priorities of "P1" to "P5". The priorities define the order and importance of the action to be undertaken in order to reduce risk.

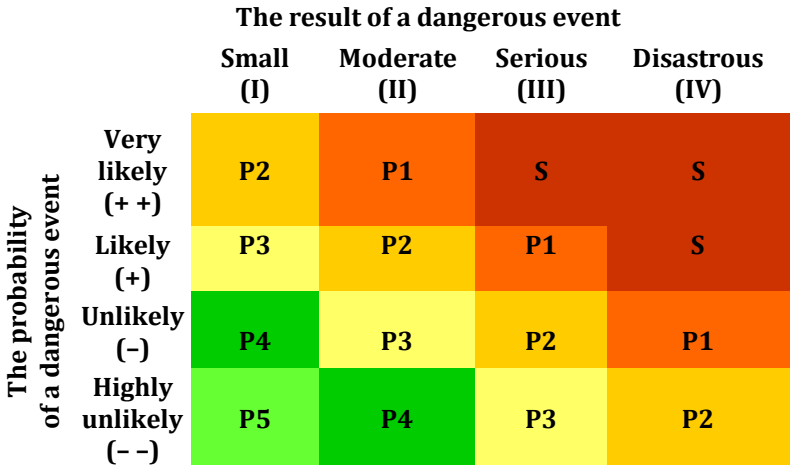

Figure 4. The 4x4 risk matrix (www.risk assessment matrix.com)

The 5x5 risk matrix (MIL-STD-882B) was formed by estimating risk in the armed forces of the United States, and the mentioned matrix is implemented in the American military standard (American Military Standard or the abbreviation MIL-STD), which recommends three types of the risk assessment matrix of this type, namely: (1) 4x6 (MIL-STD-882C), (2) 5x5 (MIL-STD-882B) and (3) 4x5 (MIL-STD-882D). The 5x5 risk matrix (MIL-STD-882C) comprises five levels (1 – Negligible, 2 – Minor, 3 – Moderate, 4 – Significant and 5 – Severe), or a qualitative description of the effects of the event/impact which relates to professional illnesses, injuries, a loss of equipment and the hours of operation and the environmental impact. The interpretation of the 5x5 risk matrix for the purpose of assessing the risk of MIL-STD-882B is shown in Figure 5.

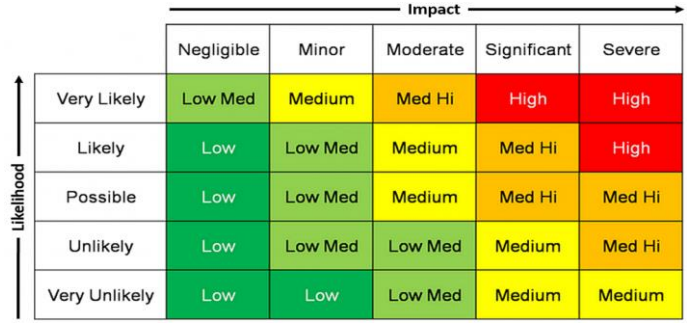

Figure 5. The 5x5 risk matrix (www.risk assessment matrix.com)

The quantity of the description and definition of the probability/likelihood of an adverse event is represented by the five levels (1 – Very Unlikely, 2 – Unlikely, 3 – Possible, 4 – Likely and 5 – Very Likely). When using this risk matrix, five quantitative descriptions of the risk level are identified (Low, Low Medium, Medium, Medium High and High). Risk is considered to be unacceptable, if it is estimated to be Very High and High, and acceptable, if it belongs to the field of secondary (Medium, Low Medium) or Low risk.

5. Conclusion

Decision-making is a process very similar to the problem-solving process in that decision-making also actually determines what needs to be done, ultimately aimed at taking an action. Accordingly, a decision is a specific commitment to an action, but does not end with a choice of some action, because the selection of an action is based on the consequences the DM expects from the action. Here, it is possible to notice the two risk constituents: a likelihood and a consequence. In order to make good decisions, it is necessary to go through the risk management and risk assessment processes appearing in the decision-making process.

In the modern literature, there are a multitude of risk assessment methods; therefore, the problem of the selection of an adequate method against the process for which risk is assessed, or valorized, appears. In this paper, a group of the methods considered to be basic for other methods, and simultaneously the simplest for understanding the significance and essence of risk assessment in one of decision-making segments, are presented.

Based on the foregoing, it is possible to conclude that the preference favoring the use of the risk matrix in the risk assessment process reflects in the fact that there is no possibility of accepting risks present in the unsafe work domain; consequently, it produces a possibility of making a large number of administrative and engineering decisions intended to reducing risk to an acceptable level. However, practical experience has shown that, when using the risk matrix, risk assessors are faced with a certain kind of limitations, including:

a possibility of only applying the risk matrix to an identified threat or harm, or of the risk matrix not being the tool for hazard identification or identification,

a high degree of subjectivity in risk assessment, and

a possibility of only a comparative analysis of the risk level (Kovacevic & Stoiljkovic, 2019).

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