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Occupational Health and Safety Risk Assessment Using the MAXM Method

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Abstract – This study proposes a new calculation method for the evaluation of hazards for occupational safety and health called Multiple AXes Matrices – MAXM. The protection of workers from workplace threats that can cause unwanted events is a basic condition for guaranteeing these fair, safe and humane working conditions for employees. The purpose of this risk assessment activity is to determine the severity and likelihood of hazardous consequences (i.e., possible occupational accidents and diseases). Acute and chronic effects on worker safety and health must be considered.

Key words: Risk Assessment, Hazard, Occupational Health and Safety Risk, Severity, Probability, Occupational Accidents, Occupational Diseases, Multiple AXes Matrices – MAXM.

I. INTRODUCTION

Risk assessment can be defined as the process of assessing the risk to the health and safety of workers during work, arising from the circumstances of the occurrence of a hazard at the workplace.

Risk assessment is the overall process of (1) risk identification (the process of finding, recognizing, and describing risks), (2) risk analysis (the process of understanding the nature of risk and determining the level of risk), and (3) evaluating of risks (process of comparing the results of the risk analysis with the risk criteria to determine whether the risk and/or its magnitude is acceptable or tolerable).

Hazard is a source or situation with the potential to cause harm and health problems, i.e., a negative effect on a person's physical, mental or cognitive state.

Risk is the effect of uncertainty. Occupational health and safety risk: the combination of the probability of occurrence of a hazardous work-related event or exposure and the severity of injury and ill health that may be caused by the event or exposure.

Work accidents and occupational diseases are dysfunctions of the work system, generated by the irregularities, qualities, intrinsic properties, etc., of its constituent elements.

Dysfunctions in the work system do not always lead to injury or changes in the health status of the performer (worker), but only in the situation where a causal chain is established, the last link of which is the meeting between the victim and the factors that harm him (risks of injury and occupational disease).

However, the analysis of the biunivocal relationship risk factor - prevention measure within the work system offers the possibility of a systematic approach to the issue of safety and health at work, respectively the etiology and prevention of work accidents and occupational diseases. Often a risk assessment will use a risk scoring system to assign a numerical value to each risk based on its severity and likelihood of occurrence. A risk assessment matrix consists of a two-dimensional grid with adverse effect categories on one axis and likelihood or probability categories on the other axis. Grid cells are used to indicate risk [1].

II. OCCUPATIONAL RISK ASSESSMENT – CONCEPTS, METHODS, APPROACHES, CLASSIFICATION, RISK CALCULATION AND ESTIMATION TECHNIQUES

Several risk assessment methods are available, ranging from expert methods to participatory methods, from simple methods to complex methods.

Risk assessment concepts

There are two possibilities for assessing the level of risk in a work environment:

a. post-accident / occupational disease evaluation ("a posteriori") - statistical analysis based on work accidents and occupational diseases;

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b. pre-accident/occupational disease assessment ("a priori") is based on risk analysis, before it becomes an accident or occupational disease [2];

Categories of methods in occupational health and safety risk assessment.

Risk assessment based on exposure [03], tasks (task-based risk assessment) [4], observations and inspections, there and accident analysis, literature and standards [7], consultation and involvement of workers [8], based on advanced technologies [6], [9].

Main approaches to risk assessment: inductive and deductive.

A. *The inductive method of risk assessment relies on observations and empirical data to draw general conclusions.*

The deductive method of risk assessment is based on logical and rational deductions. Several examples are given below: historical data analysis [10], incident analysis [11], cause and effect analysis (FMEA) [12], Delphi method [13]. cluster analysis [14], decision tree method [15], incident history analysis [16], brainstorming method [17], case studies: [18], direct observations [19], future event analysis (AEA) [20],

Examples of deductive methods: scenario analysis [21], rule-based method [22], qualitative and quantitative analysis [23], hazard and operability analysis (HAZOP) [24], failure mode and effects analysis (AMDE) [25], risk assessment matrix (MER) [01], hazard analysis and critical control points (HACCP) [26], cost-effectiveness analysis method (ACE) [27], mathematical risk analysis [28], formal risk assessment method (FERA) [29], cost-benefit analysis (ACB) [30], criteria-based method [31].

Examples of combined (inductive and deductive) risk assessment methods are:

a. The risk analysis method based on event trees (Event Tree Analysis - ETA) [32]

b. Decision tree method (Decision Method) [33]

B. *Occupational risk assessment methods – Deterministic, probabilistic and mixed methods.*

Deterministic methods are based on the identification and assessment of risks based on existing experience, expertise and knowledge. Probabilistic methods, on the other hand, use mathematical and statistical models to estimate risk based on probabilities and frequencies.

The combined approach: integrating deterministic and probabilistic aspects

Classification of methods from the point of view of the results obtained.

The results obtained from occupational risk assessments are qualitative determinations (recommendations) or quantitative (risk level indices). The main difference between qualitative and quantitative risk analysis is the basis of risk assessment. Qualitative risk analysis is based on a person's perception or judgment, while quantitative risk analysis is based on verified and specific data.

III. RESEARCH METHODOLOGY

Theoretical definition of the risk assessment method

Through an integrated and continuous approach to risk, organizations can create a safe, healthy and sustainable work environment, contributing to the well-being of employees and the long-term success of the business. The use of data and information gained from experience and periodic adjustments in the occupational health and safety program reduce the probability / severity of the consequences of undesirable events.

This investigation proposes a new method called MAXM for determining the level of risk. MAXM is a pre-accident / occupational disease assessment ("a priori"), based on risk exposure, considering the combined risk approach, the results obtained from occupational risk assessments are qualitative (recommendations) or quantitative (risk level index).

The assessment (assessment = determination + analysis + estimation) of work processes and the identification of potential critical points are essential aspects for the development of an effective occupational health and safety risk assessment plan.

A. *Proposed stages for the evaluation*

The stages proposed for the evaluation method are:

a. Identification of work processes:
   - listing all the work processes carried out in the organization;

b. Identifying critical points:
   - identifying the stages or places within each process that present significant risks for safety and health at work, we will pay attention to activities with potential serious or frequent consequences;

c. Risk analysis:
   - for each critical point identified, we will perform a risk analysis to determine the probability and potential impact of unwanted events;
   - using a risk assessment matrix to classify and prioritize risks according to their severity.

d. Planning measures to eliminate or reduce the risk.

e. Elaboration of organizational management recommendations for each risk identified and evaluated according to the type of response (strategy adopted) considered the most appropriate, the final decision in this regard belongs to the leader of the organization.

f. Recording findings, monitoring and reviewing risk assessment and updating when necessary. (Risk monitoring)

The risk management and review report clearly consist of two parts in relation to:

- risks with a high and very high level of exposure, which can influence the achievement of the objectives specific to the organizational structure;
- the implementation stage of the preventive measures, at the reporting date.

B. *Risk matrix for risk calculation*

The Risk Assessment Matrix, also known as the Risk Matrix, is a tool used in risk management to assess and classify risks according to their probability and the impact they can have on the objectives of a project, organization or activity. This matrix is useful for prioritizing risks and guiding risk management efforts.

The risk assessment matrix is represented in the form of a table with two main axes:

- Probability (or frequency): This indicates how likely a particular risk event is to occur.
- Impact (or severity): This measures the extent of the negative consequences of a risk event should it materialize.

C. *Likelihood and Impact Assessment*

In this stage of the methodology several actions should be considered as following:

- Determine the probability: we estimate the probability of the occurrence of the risk on a scale from 1 to 5 (1 - unlikely, 5 - very likely).
- Determine the impact: we evaluate the impact of the risk if it materializes, on a scale from 1 to 5 (1 - low impact, 5 - major impact).

Depending on the assignment for probability and impact, each risk event is placed in one of the categories of the matrix. This generates five distinct zones:

1. Minimal risks: events of low probability and impact that may require only routine attention or light management.
2. Moderate risks: no action is required, but the hazard must be monitored (eg worker training);
3. Significant risks: actions are needed and small measures must be implemented in the medium term;
4. Major risks: actions are needed, but work can continue if at least organizational measures have been taken;
5. Critical risks: immediate action is required and the cessation of work until this severity and/or probability of risk is reduced by technical measures.

In data analysis, the use of evaluation matrices with different reporting axes (Multiple Axe's Matrices – MAXM) can be essential to obtain a detailed investigation of the performance of a model or method. This is important because different reporting axes can highlight different aspects of performance, providing a completer and more accurate picture.

For each danger / risk factor identified, the highest consequence of the possible possibilities is established depending on the exposure / frequency as shown in Fig 1.

The calculation formula for determining the risk value is:

$$R = (R1 + R2) * R3 \qquad (1)$$

where ***R*** **–** total risk;

- ***R1*** – the risk determined using the matrix with the axes: severity / probability;
- ***R2*** – the risk determined using the matrix with the axes: R1 / time scale (represents the actual working time in the areas with maximum risk);
- ***R3*** – risk determined using the axis matrix: frequency of unwanted events / duration of exposure.

Characteristics of **R1 -** the risk determined using the matrix with the axes: severity / probability:

- Purpose: Provides an overview of the probability of an incident occurring and its severity;
- Axes: severity / probability as shown in Fig 2, Table 1, and Table 2.

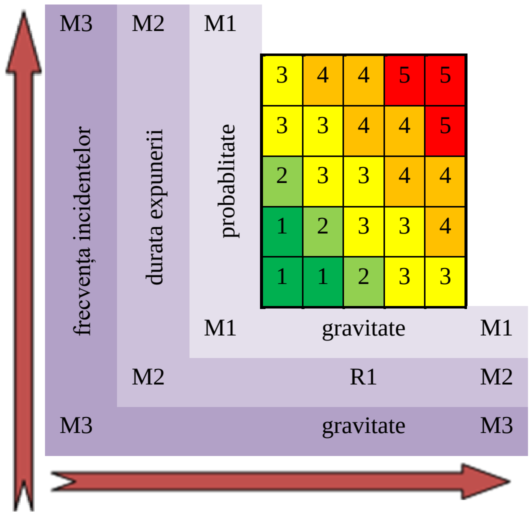

Fig 1 Establishing the maximum consequence depending on exposure and frequency

Probability	negligible	minority	significantly	majority	severe
almost sure	3	4	4	5	5
probable	3	3	4	4	5
moderate	2	3	3	4	4
unlikely	1	2	3	3	4
rare	1	1	2	3	3

Severity

Fig 2. The risk determined according to the axis of probability and the axis of severity

Table 1 Probability

probability	1. Rare – unlikely to happen and/or have minor or negligible consequences;
	2. Unlikely – likely to happen and/or have moderate consequences;
	3. Moderate – likely to happen and/or have serious consequences;
	4. Likely – almost certain to happen and/or have major consequences;
	5. Almost certain – certain to happen and/or have major consequences.

Table 2 Severity

severity	1. Insignificant - will not cause serious injury or illness;
	2. Minor – may cause injury or illness, only to a slight extent;
	3. Significant – may cause injury or illness that may require medical attention, but limited treatment;
	4. Major – can cause irreversible damage or diseases that require constant medical care;
	5. Severe - can lead to death.

Duration of exposure	R 1	R 1	R 1	R 1	R 1
almost sure	3	4	4	5	5
probable	3	3	4	4	5
moderate	2	3	3	4	4
unlikely	1	2	3	3	4
rare	1	1	2	3	3

The activities are performed in high-risk areas

Fig 3. The risk determined according to the duration of the exposure and R1

Table 3 Duration of exposure

Duration of exposure	1. 0 - 10 % of the daily work schedule
	2. 10 - 25 % of the daily work schedule
	3. 25 - 50 % of the daily work schedule
	4. 50 - 75 % of the daily work schedule
	5. 75-100% of the daily work schedule

Table 4 Activities performed in high-risk areas

Activities performed in high-risk areas	1. Initial risk value
	2. Initial risk value
	3. Initial risk value
	4. Initial risk value
	5. Initial risk value

Characteristics of **R2** – the risk determined using the matrix with the axes: R1 / time scale (represents the actual working time in the maximum risk area): Purpose: determining the activities to be performed in high-risk areas; Axes: R 1 / duration of exposure, as shown in Fig. 3, Table 3, and Table 4.

Characteristics of **R3** – risk determined using the axis matrix: frequency of previous incidents / severity: Purpose: determination of work tasks with a high risk of injury; Axes: frequency of previous incidents / severity as shown in Fig 4, Table 5, and Table 6.

Frequency of previous incidents	negligible	minority	significantly	majority	severe
weekly	3	4	4	5	5
monthly	3	3	4	4	5
annual	2	3	3	4	4
1-5 years	1	2	3	3	4
over 5 years	1	1	2	3	3

Severity

Fig 4. The risk determined according to the previous incidents and their severity

Table 5 Frequency of previous incidents

frequency of previous incidents	1. over 5 years
	2. 1 - 5 years
	3. annually
	4. monthly
	5. weekly

Table 6 Severity

severity	1. Insignificant - will not cause serious injury or illness
	2. Minor – may cause injury or illness, only to a slight extent
	3. Significant – may cause injury or illness that may require medical attention but limited treatment
	4. Major - can cause irreversible damage or illness that requires constant medical care
	5. Severe - can lead to death

By properly evaluating and interpreting the risk assessment matrix, we can make informed decisions and implement effective strategies to manage and control risks appropriately, here is a guide on the numerical values and their representation as a result of the analysis:

a. 1-10: Acceptable – no further action may be required and maintenance of control measures is encouraged;
b. 11-30: Tolerable – should be reviewed in due time to realize improvement strategies;
c. 31-50: Unacceptable – we must implement cessation of activities and immediate action.

Among the main advantages of the proposed MAXM methods, one can mention:

- Determining the level of exposure: exposure time provides a clear perspective to assess how long a worker is likely to be exposed to specific workplace hazards. This information is necessary to calculate the associated risk.
- Prioritization of prevention measures allows the organization to identify and prioritize prevention and protection measures according to the duration and frequency of risk exposure. Thus, resources can be allocated effectively to address the most critical aspects of occupational safety and health.
- Employee awareness: provides a basis for awareness and training of employees in relation to the specific risks to which they are exposed and the necessary precautions.

- Worker Involvement: Integrating exposure time into the risk assessment process can stimulate active worker involvement in identifying and managing workplace risks. This can help raise awareness and improve collaboration to promote a safe working environment.
- Flexibility in risk reduction strategies: knowledge of exposure time can facilitate the development and implementation of specific risk reduction strategies to lessen the impact on workers. This provides the organization with a useful tool for continuous adaptation to changes in the work environment.
- Addressing deficiencies in employee training: identifying high-risk periods can lead to improved training and education programs, focusing on critical aspects of occupational safety and health depending on the duration of exposure to risks.
- Efficiency in the allocation of resources: detailed knowledge of exposure time allows the organization to allocate resources efficiently, focusing on those aspects that have the greatest impact on safety and health at work.
- Measuring the effectiveness of preventive measures: the use of exposure time can also serve as an indicator of the effectiveness of implemented preventive measures. Monitoring this parameter over time can highlight possible improvements or necessary adjustments in risk management strategies.
- Individual level monitoring: the use of exposure time can allow for individual level monitoring of workers, identifying those who are at higher risk. This aspect can contribute to the implementation of personalized protection and training measures.
- Improving safety culture: focusing on exposure time can promote a safety culture in the organization, where employees become more aware of the impact of exposure to risk and take greater responsibility for adopting safe behaviors.
- Identifying trends over time: analyzing long-term exposure time can reveal trends and patterns that can be useful for identifying potential risks in the future and for developing proactive prevention strategies.
- Management of psychosocial factors: exposure time can contribute to the assessment of psychosocial factors, such as stress and fatigue, having a significant impact on the mental and physical health of workers. This aspect can be integrated into risk management strategies.
- Involvement of external collaborators: when the organization works with subcontractors or external partners, exposure time assessment can be useful in communicating and managing risks throughout the supply chain, ensuring an integrated approach to occupational safety and health.
- Stimulating innovation in workplace safety: using exposure time can stimulate innovation in the development and implementation of new technologies or practices that reduce exposure time and improve workplace safety.
- Holistic approach to employee well-being: exposure time-based risk assessment can serve as a tool in a holistic approach to employee well-being, addressing both physical and psychological aspects of workplace health.

Several disadvantages were also identified from the outset:

- Sensitivity to the variability of work activities: certain activities may involve exposure to variable risks, depending on various conditions. Using exposure time alone may not account for this variation and may underestimate or overestimate the true risk.
- Difficulty of accurate estimation: accurate calculation of exposure time can be difficult, especially in situations where workers carry out multiple activities or in unstable working conditions.
- Neglecting other relevant factors: Focusing exclusively on exposure time may lead to the neglect of other critical factors, such as individual worker characteristics, equipment used or additional protective measures.
- Variability in data interpretation: different people or teams may interpret and quantify exposure time in different ways, which can lead to inconsistencies in risk assessment and the development of prevention measures.
- Costs associated with data collection: Collection and analysis of exposure time data can require significant resources, including monitoring devices, specialized software, and staff training, generating additional costs for the organization.

IV. DISCUSSION

"Risk" is the product of hazard and exposure. Therefore, risks can be reduced by controlling or eliminating hazards or by reducing worker exposure to hazards. Risk assessments help employers understand workplace hazards and prioritize hazards for ongoing control.

The frequency index of previous incidents has the greatest influence in the calculation formula because it specifically shows the real situation of safety and health within the organization because unwanted events (accidents and occupational diseases) show the degree of risk assumed, being interconnected with experience and the skills of the performer, the situation of the work environment, the size of the work load and the condition of the means of production.

- Calculating the frequency of previous incidents can serve as a basis for a better risk management. Assessing specific risks: By analyzing the frequency of past incidents in different areas or for different activities, organizations can identify the specific risks they face and prioritize prevention and protection measures accordingly.

- Setting improvement goals: If the frequency of incidents is high in certain areas or activities, organizations can set specific goals to reduce it and develop action plans to improve safety and prevent accidents.
- Monitoring progress by tracking the frequency of incidents over time, organizations can assess the effectiveness of the prevention and intervention measures taken. A reduction in the frequency of incidents over time may indicate improved workplace safety and the effectiveness of risk management programs.
- Compliance with regulations and standards: Calculating the frequency of past incidents can help organizations stay compliant with occupational health and safety regulations and standards. By identifying and mitigating the risks associated with past incidents, organizations can avoid penalties and fines for non-compliance with safety regulations.
- Improved safety culture: The frequency of previous incidents can serve as an indicator of the safety culture in the organization. A low frequency of incidents may reflect a strong commitment to occupational safety and health, while a high frequency may indicate a need to strengthen workplace safety awareness and involvement.

V. CONCLUSIONS AND FURTHER WORK

Calculating the frequency of past incidents is an essential tool in managing risk and promoting a safe and healthy work environment for all employees. By analyzing and using this data correctly, organizations can take concrete steps to reduce risks and protect the health and safety of employees.

The proposed method aims to be an applicable tool for identifying the main sources of risk and prioritizing the implementation of control measures.

The method serves as a basis for integrating the occupational health and health (OSH) management system with the requirements of European legislation and known methods used by expert occupational risk assessors. It can be modified and created by each specialized user based on the directions established by the MAXMR method, emphasizing the importance of organization management in OSH and the effects of the external environment that are not sufficiently addressed in current methods.

This work should be considered as the result of an initial implementation phase, and researchers and practitioners are invited to contribute to its further development. Further work aims to validate the proposed MAXM method via a series of case studies and comparison with existing methods.

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