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METHODS FOR IDENTIFYING AND ASSESSING RISKS OF OCCUPATIONAL INJURY AND DISEASE - THEIR SUITABILITY FOR ASSESSING EMERGING RISKS

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Abstract: *The integration of digital technologies, including industrial automation, artificial intelligence, advanced robotics, the Internet of Things (IoT), additive manufacturing (3D printing), etc., is radically transforming industrial and organizational work environments. These emerging technologies bring both significant opportunities for efficiency and innovation, but also introduce new and complex risks to worker safety (exposure to electromagnetic radiation, cognitive overload, cyber risks, potential for accidents caused by human-machine interactions, etc.). Effectively identifying, assessing and managing these emerging risks is critical to ensuring a safe, healthy and efficient workplace atmosphere. The purpose of this research, which is based on previous theoretical and empirical studies, was to: identify the most used methods/methodologies/tools for hazard identification, risk analysis and occupational injury and disease risk assessment; the comparative analysis of the selected methods, to highlight their advantages and disadvantages, respectively their limitations. Also, the research sought to examine the effectiveness and suitability of the selected methods for identifying and assessing new risks emerged from the adoption of digital technologies in technological and manufacturing processes. In the context of rapid technological evolution, it is essential to improve and adapt these methods to be as accurate, adaptable and to remain relevant, thus ensuring better protection of the working environment and more effective risk management in an era of production more and more digitized.*

Keywords: *method, risk, emerging risk, risk analysis, safety*

1. INTRODUCTION

The integration of digital technologies (industrial automation, artificial intelligence, advanced robotics, Internet of Things (IoT), additive manufacturing (3D printing), augmented reality (AR) and virtual reality (VR), etc.), radically transforms industrial and organizational work environments. These emerging technologies bring both significant opportunities for efficiency and innovation, but also introduce new and complex risks to worker safety (exposure to electromagnetic radiation, cognitive overload, cyber risks, potential for accidents caused by human-machine interactions, etc.) [1–3].

The assessment of emerging risks identified as a result of the adoption of new digital technologies in organizations requires the application of methods capable of addressing the uncertainties and complexities specific to this domain.

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This research seeks to enhance the existing knowledge in this field by setting the following objectives:

1. Comparative analysis of the most commonly used methods/methodologies/tools for hazard identification, risk analysis and risk assessment related to workplace injury and illness, in order to highlight their advantages and disadvantages, respectively their limitations. The study also aims to analyze the effectiveness and suitability of the selected methods for identifying and assessing new risks emerged from the adoption of digital technologies in technological and manufacturing processes.
2. Development of a set of issues that we recommend for analysis and taking into consideration in order to effectively address the risks associated with the implementation of digital systems.

The research begins by briefly presenting the methodology used to identify and select the methods/methodologies/tools for identifying and evaluating the risks associated with work-related injuries and illnesses, followed by the findings obtained from analyzing the data and the scientific literature on the selected methods. In the last part, we shared our study conclusions along with the existing research constraints in this field.

2. METHODOLOGY

The method by which the identification and selection of methods/methodologies/tools for hazard identification, risk analysis and risk assessment of occupational injury and ill health is carried out is presented in Figure 1:

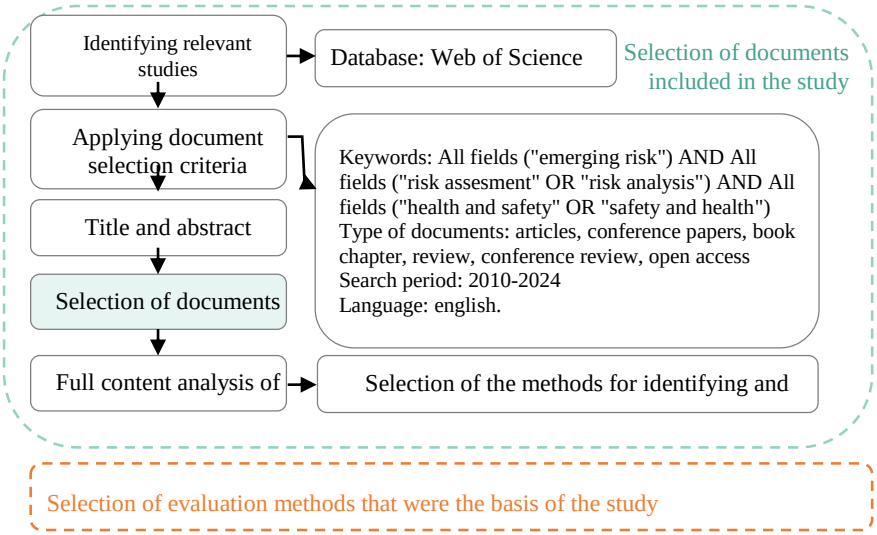

Figure 1. The approach used to select the documents analyzed in the study

3. RESULTS AND DISCUSSION

Risk assessment is an essential process within every organization as it enables the systematic identification and understanding of risks, facilitating informed decision-making and the development of risk management strategies [4, 5].

This process involves a detailed analysis of the working system, the technologies used, the regulatory framework, all operational aspects including business processes. Risk assessment is not only limited to their identification, but also involves a detailed analysis of the impact and probability of each risk. This analysis is essential for prioritizing risks, taking proactive measures and avoiding or reducing the negative impact of risks [4].

A brief presentation of the risk assessment process was made in Figure 2.

In this study, 8 frequently used methods of identification and assessment of occupational injury and disease risks were selected and analyzed: scenario analysis, cause-effect analysis (ISHIKAWA diagram; FISHBONE diagram), analysis of failure modes and effects (FMEA), hazard and operability study (HAZOP), level of protection analysis (LOPA), risk assessment matrix, Bow-Tie analysis and the I.N.C.D.P.M method (developed by the "Alexandru Darabonț" National Research and Development Institute for Labor Protection from Bucharest Romania).

A detailed presentation of the selected evaluation methods was not included, as this analysis, which is based on previous theoretical and empirical studies, focused on identifying the advantages and limitations/constraints of each method, the results obtained being synthesized and presented in Table 1:

Table 1. Methods for the identification and evaluation of risks related to occupational injury and illness – advantages and limitations/constraints

	The advantages of the method	**Limitations/constraints**
Scenario analysis [9, 10]	- qualitative analysis method, but can be adapted to include quantitative elements; - allows the anticipation and management of potential risks, as it is based on the development of hypothetical scenarios, based on different variables and circumstances; - allows the prioritization of risks, by using a structured approach; - enables risk assessment in a dynamic context, given that scenarios can be adapted to reflect various conditions and technological developments; - through the detailed analysis of the various possibilities and consequences, it contributes to the improvement of the decisions taken.	- the process of collecting data, building scenarios and analyzing them is a complex and lengthy process; - incorrect or incomplete input data can lead to erroneous conclusions and affect the quality of the analysis results; - sometimes the ability to predict all risks is limited, given that it is almost impossible to anticipate all possible variables and interactions.

Cause-effect analysis (ISHIKAWA diagram; FISHBONE diagram) [9, 10]	- method of systematic, structured analysis, used to identify the potential causes that contribute to the emergence of a certain risk; - allows the development of effective preventive measures, following the identification of the root causes of the issue/danger.	- the analysis is difficult to manage in the case of complex situations, with multiple interrelated causes; - the analysis focuses on the immediate causes thus, it is possible to neglect the wider context or factors that may contribute to the emergence of risks; - the analysis focuses on identifying causes but does not provide direct information on the impact or likelihood of identified risks; thus, it is necessary to use other complementary methods to evaluate these aspects.
Hazard and operability study (HAZOP) [11–13]	- method of systematic, qualitative, structured analysis, used to identify potential hazards and assess injury risks; - involves teams of experts from different fields; - focuses on identifying hazards before they manifest themselves in incidents or events; - allows the identification of potential operational hazards (e.g. that may arise due to abnormal operating conditions) and the assessment of the impact of deviations from design specifications; - allows adaptation to the specifics of each process.	- the quality of the HAZOP analysis is directly proportional to the level of experience and knowledge of the team members; - assessment of the severity, frequency and detectability of risks is often subjective and may vary between team members; - focuses on individual failure modes without adequately considering the complex interactions between them.
Bow-Tie Analysis [9, 14]	- graphic, systematic analysis method used for risk management, for analyzing the effectiveness of checks in relation to different risks; - allows a thorough analysis of the factors that can contribute to the occurrence of a critical event and the effects/ consequences that this event can have, thus facilitating the implementation of measures to prevent and reduce the consequences; - allows adaptation to the specifics and particular needs of each organization.	- is appropriate for assessing emerging risks associated with new digital technologies, but to be effective it must be used in conjunction with other risk assessment methods and supported by expertise and up-to-date data; - creating a Bow-Tie chart is a complex process and requires specialized expertise; - the method is effective for risk prioritization due to its logical structure and the ability to identify the causes, effects and control measures associated with each risk; - analysis is not very adaptable in dynamic risk management;

		- the analysis focuses on single critical events and is not suitable for risk analysis involving complex interactions between events; - the quality and usefulness of Bow-Tie analysis is dependent on the quality of the input data. Incomplete or inaccurate information can lead to erroneous conclusions and the implementation of ineffective control measures.
The I.N.C.D.P.M method (developed by the National Research-Development Institute for Labor Protection "Alexandru Darabonț" from Bucharest, Romania) [10, 15–17]	- systematic, standardized analysis method used to identify and evaluate risks associated with occupational injuries and illnesses; - in order to take into account the evolution of risks over time, it is necessary to periodically update and continuously monitor the work system; thus, adjustments can be made depending on the evolution of processes and the appearance of new risks or changes to existing ones.	- the results obtained may be influenced by the individual perceptions and experiences of those carrying out the assessment, which may lead to subjective interpretations and variations in identifying and evaluating risks; - the lack of accurate and up-to-date data may affect the accuracy and relevance of the risk assessment; - in order for the method to be suitable for the specifics of different processes, it is necessary to adjust the risk assessment criteria and procedures according to the specifics of each operational process; - for the method to be effective in addressing complex interactions between events, careful and well-supported implementation (resources, accurate and detailed data, objectivity in the evaluation process, etc.) is required.
Failure Modes and Effects Analysis (FMEA) [11, 18]	- systematic, semi-quantitative analysis method used to detect potential failure modes within a system, product or process before they occur in practice; - allows the identification of risks that could affect the safety of operators; - by calculating the RPN (Risk Priority Number), it helps to prioritize risks (according to severity, frequency of risks) and focus on the most critical aspects;	- is effective in identifying known risks, but may not be as effective in detecting emerging risks, especially in the case of new technologies; - assessment of severity, frequency of risks is often subjective and may vary between team members. This can lead to differences in the calculation of RPN and implicitly, in the prioritization of risks;

	- allows detailed assessment of the impact of these risks (causes and consequences of failure).	- focuses on individual failure modes without adequately considering the complex interactions between them.
Analysis of protection levels (LOPA) [10–12]	- method of systematic, semi-quantitative analysis, used to assess occupational risks and determine the effectiveness of protective measures in a system or process; - it allows the prioritization of safety measures necessary to achieve the acceptable level of risk; - enables an integrated, comprehensive approach to risk analysis by using it in combination with other risk analysis methods; - allows adaptation to the specifics and particular needs of each organization.	- incorrect or incomplete input data can affect the quality of the analysis results; - calculating the probabilities and effectiveness of protective measures can be complex, requiring a high level of expertise and knowledge; - assessing the severity and likelihood of risks is often subjective and may vary between team members; - it is less effective in addressing global risks; - does not provide an adequate approach to human and organizational factors.
Risk assessment matrix [4, 9, 12]	- structured, systematic, quantitative and reproducible analysis method in risk management; - allows risks to be prioritized according to criteria such as likelihood of occurrence and potential effects on the safety and health of workers; - the matrix can be used for risk monitoring and periodic updating of the risk assessment according to changes in the work system.	- it is not flexible or detailed enough to enable the management of complex risks or to address the complex interactions between different risks; - the method is subjective, the assessment of probability and impact being influenced by the individual perceptions and experiences of those involved in the assessment process; - the lack of accurate and up-to-date data and information can influence the effectiveness of the assessment.

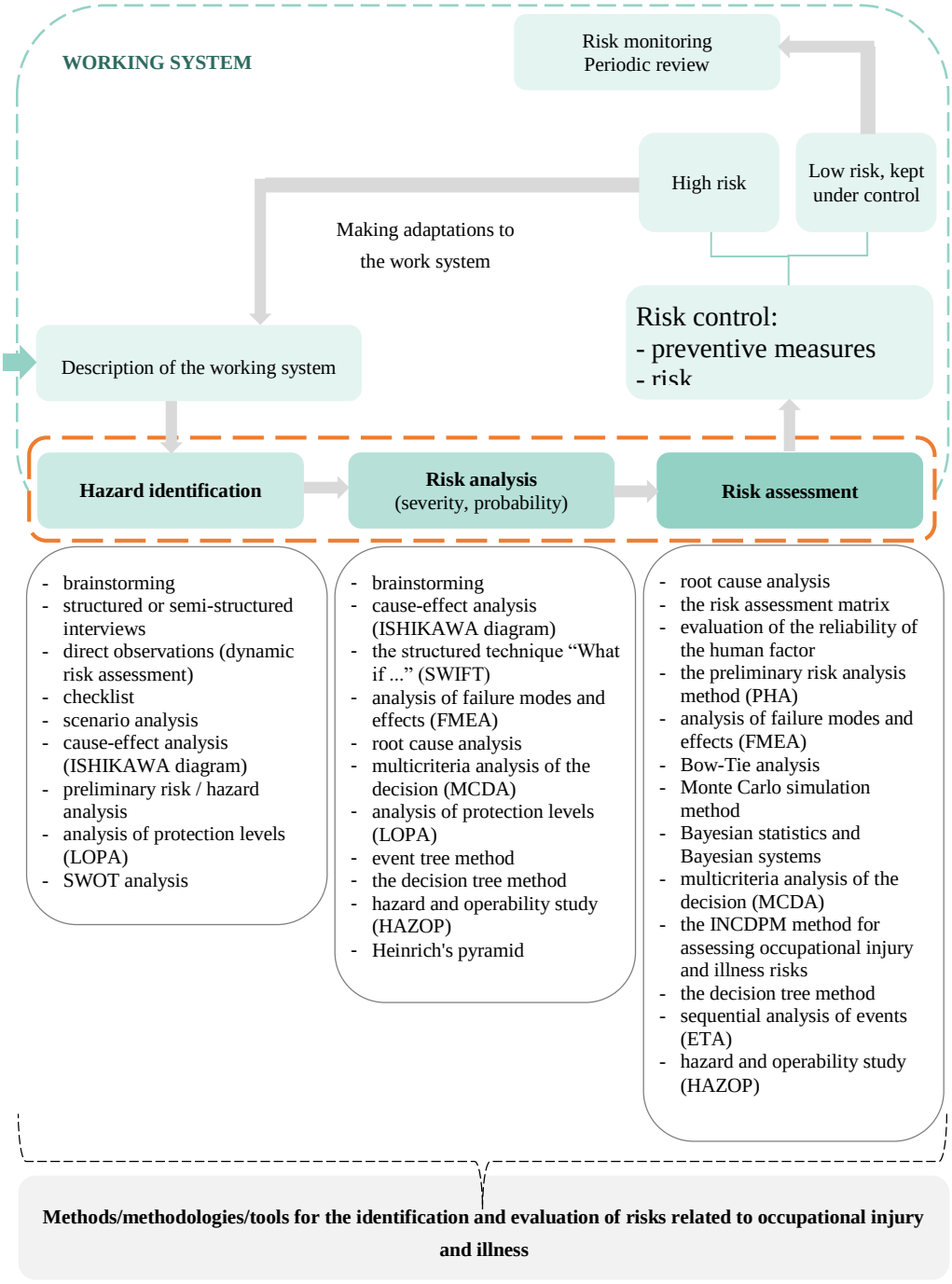

Figure 2. Synthesis of the risk assessment process [6–8]

Table 2 summarizes the findings derived from comparing certain aspects regarding the selected methods, precisely to have a clearer perspective on the advantages and limitations/constraints of the analyzed methods:

Table 2. Methods for the identification and evaluation of risks related to occupational injury and illness – comparative analysis [4, 9, 18, 10–17]

	Qualitative analysis method	Semi-qualitative analysis	Semi-quantitative analysis	Quantitative analysis method				
The method of identifying and evaluating risks / Aspects analyzed	**Scenario analysis**	**Ishikawa /Fishbone**	**HAZOP**	**Bow-Tie**	**INCDPM**	**FMEA**	**LOPA**	**Risk matrix**
It is suitable for assessing emerging risks ?	YES	YES	YES	YES	NO	NO	YES	YES
It involves a multidisciplinary analysis team ?	YES	YES	YES	YES	YES	YES	YES	YES
Take into account the evolution of risks over time ?	YES	NO	NO	NO	YES	NO	NO	YES
It is a subjective method ?	YES	YES	YES	NO	YES	YES	YES	YES
Allows risk prioritization ?	YES	NO	YES	YES	YES	YES	YES	YES
It allows adaptation to the specifics of different processes ?	YES	YES	YES	YES	YES	YES	YES	YES
It addresses the complex interactions between events ?	YES	NO	NO	NO	YES	NO	NO	NO

As can be seen, each of these methods has its own advantages and limitations and may be more suitable depending on the specific context of the organization, the complexity and the specificity of the emerging risks associated with the integration of digital technologies.

These "classical" methods of identifying and assessing occupational injury and disease risks, developed in the 20th century, focused on the traditional physical, chemical, biological, ergonomic risks associated with workplaces in industry, construction, agriculture and other similar sectors. These methods have been designed to address obvious and tangible risks that can lead to occupational accidents or illnesses, such as exposure to hazardous substances, poor working conditions or unsafe equipment. With the rapid technological evolution and the integration of digital solutions within organizations, new types of risks have emerged that do not fit into traditional categories.

Therefore, in order to address the complexity of the risks associated with digital systems, and to carry out a comprehensive and effective evaluation of the risks of

occupational injury and illness, a systematic and structured approach that takes into account a number of critical issues is essential [4]:

- developing within organizations a positive safety culture, supported by management commitment, active worker involvement and continuous improvement efforts – an aspect that is essential for improving worker safety [4, 19];
- analysis of dependencies and interactions between all components of the work system: human factors/executor, equipment, technologies, technological processes (manufacturing processes, maintenance processes, emergency response plans, etc.), environmental factors, management factors, etc., precisely to identify the specific risks associated with each technology used [4];
- adapting the predefined lists of risks related to occupational injury and illness, by including the emerging, specific risks associated with new digital technologies (probability of cyber attacks, impact on sensitive data, consequences on the well-being of employees, including both mental and physical aspects, etc.). These risks are usually complex and interconnected, and for this reason, a multifactorial and multidisciplinary approach is essential precisely in order to correctly identify and assess them;
- developing risk scenarios specific to new digital technologies and assessing their impact on occupational safety and health;
- applying assessment methodologies that address proactive risk management, thus improving worker safety by reducing the likelihood of events occurring;
- the implementation of continuous risk monitoring programs, assessing how effective the implemented control measures are and periodically updating the risk assessment, as new risks are identified or new technologies are integrated;
- the integration of digital technologies (artificial intelligence, big data, etc.) in the risk assessment process due to the advantages they imply, for example: the possibility of collecting and analyzing data in real time; the possibility of identifying trends; the possibility of constant monitoring of working conditions and safety parameters, thus providing real-time alerts about potential dangers; the possibility of rapid generation of personalized reports, thus facilitating the interpretation and communication of identified risks to all levels of the organization, etc.

As can be seen from Table 2, the analyzed methods can be used to address the emerging risks associated with the integration of digital solutions, but under the conditions of their adaptation to remain relevant, to be more flexible, to include a holistic approach and to be based on an interdisciplinary collaboration, to maintain a safe and healthy work environment in the era of digital technology [20].

5. CONCLUSIONS

This study's contribution consists in:

1. Carrying out a comparative analysis of 8 selected methods for the identification and evaluation of risks related to occupational injury and illness. By comparing these methods, the study identifies the advantages and limitations/constraints of each, helping practitioners to choose the most appropriate methods for their specific needs.
2. Proposing a set of issues that we recommend for analysis and taking into consideration in order to address the complexity of the risks associated with the integration of digital systems.

In order to assure a cohesive and efficient approach to risk assessment, including emerging risks resulting from the adoption of new digital technologies, it is essential to develop and apply a methodology that is adapted to the organizational context, the complexity of the integrated technologies and the nature of the identified risks. In many cases, a combined approach, i.e. using several methods in parallel, can ensure a more proactive, comprehensive and robust approach to risk management [9].

Limitations of the research:

The present study included the conclusions obtained after analyzing a limited number of methods for the identification and evaluation of risks related to occupational injury and illness. It is necessary to analyze a greater number of methods, precisely to ensure an adequate approach to the emerging risks generated by new digital technologies.

We recommend further studies to update / adapt risk assessment procedures and tools to include emerging risks generated by digitization. An integrated approach combining cyber security expertise, risk management and occupational health is essential for this adaptation.

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