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A Risk Management Approach in Occupational Health and Safety Based on the Integration of a Weighted Composite Score

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Abstract

Occupational health and safety (OHS) is essential for protecting the life, health, and physical integrity of workers. In a complex and dynamic professional context, the prevention of occupational risks has become a priority for employers and decision-makers, going beyond legal compliance to create a safe and efficient work environment. This article explores the history and the main theoretical aspects of OHS and explores the implementation of the ISO 45001 standard and introduces managing workplace health and safety (WHS) risks based on the 5M Method and a weighted composite algorithm for OHS risk assessment integrating factors such as severity, probability, frequency of exposure, number of exposed employees, organizational response capacity, and incident history. Applied in a mixed industrial case study, this approach demonstrated superior risk prioritization compared to the classic severity–probability model. The findings have practical applications: organizations can use the Weighted Composite Score to prioritize interventions, allocate resources efficiently, and prevent high-risk incidents. The approach is adaptable across industries, supporting data-driven safety decisions. The integration of this method supports ISO 45001's principles of a systematic, proactive, and continuous improvement approach to OHS management.

Keywords: occupational health and safety; ISO 45001; employee safety; workplace accident prevention; risk management; weighted composite risk score

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1. Introduction

Health and safety of workers are essential aspects for the efficient and sustainable functioning of an organization [1]. They directly influence economic performance by reducing accidents and absenteeism, as well as the company's reputation, reflecting social responsibility and care for employees [2]. Moreover, a safe work environment contributes to increased employee satisfaction and loyalty [3]. Therefore, integrating health and safety into the organizational strategy is crucial for long-term success and sustainability [4]. Occupational health and safety (OHS) constitute a fundamental prerequisite for the effective and secure functioning of industrial operations [5]. Directive 89/391/EEC, commonly referred to as the "Framework Directive on Safety and Health at Work", establishes the fundamental principles aimed at promoting enhancements in the safety and health conditions of workers within the workplace [6]. It mandates minimum safety and health standards across the European Union while permitting Member States to uphold or implement more rigorous measures [7]. This Framework Directive is supplemented by a series of specific directives addressing particular facets of occupational safety and health. Collectively, these directives constitute the foundational legal framework for safety and health regulation within the European Union.

The international standard ISO 45001 [8] promotes a systematic approach focused on prevention and continuous improvement in the field of occupational health and safety. It requires organizations to rigorously identify risk factors, assess hazards associated with their activities, and implement effective control measures aimed at protecting both the physical health and mental well-being of employees [9]. Achieving compliance with ISO 45001 and obtaining the corresponding certification reflects an organization's active commitment to fostering a safe and healthy work environment while also enhancing its professional image and strengthening its competitive advantage in the current economic context [10].

Although the field of OHS enjoys broad consensus regarding its fundamental importance, there are still diverging hypotheses and controversial aspects that fuel both academic and practical debates. In this regard, recent advances in artificial intelligence (AI) offer transformative opportunities for OHS research and practice. By integrating large language models (LLMs) with synthetic data generation tools, novel frameworks can simulate and validate innovative safety methodologies in controlled environments. Such approaches not only address long-standing challenges in early-stage method testing but also promote more agile, evidence-based risk management strategies adaptable to complex and evolving workplaces [11]. At the same time, recent studies highlight how technological innovations are reshaping OHS practices, moving from reactive to predictive and data-driven models. Wearable sensors, IoT systems, and AI-based monitoring are increasingly used to enhance hazard detection and prevention [12]. Furthermore, immersive training tools such as AR/VR supported by artificial intelligence improve safety education and strengthen workers' engagement [13]. In high-risk sectors like mining and construction, AI and robotics are transforming inspection and monitoring, enabling proactive risk management [14]. One major point of tension concerns the relationship between regulatory compliance and safety culture: while some experts argue that adherence to standards is sufficient to reduce risks [15], others emphasize that a proactive organizational safety culture has a deeper and more lasting impact [16]. Similarly, a divide exists between approaches focused on human error, viewed as the main cause of accidents, and system-based perspectives, which analyze organizational shortcomings as the true root of safety failures [17].

Furthermore, the introduction of international standards such as ISO 45001 has sparked mixed reactions: while some consider them essential for globally aligning OHS practices, others point out that such standards can be challenging to implement in small enterprises or emerging economies [18]. Moreover, the integration of digital technologies into risk monitoring raises ethical dilemmas, being seen either as an innovative solution or as a form of excessive surveillance that undermines employee trust and autonomy [19]. Mental health, although gaining increasing recognition within OHS, is still perceived by some as a secondary issue, often delegated to human resource departments rather than treated as a core component of workplace safety [20]. These contrasting perspectives highlight the need for a balanced, interdisciplinary, and adaptable approach that addresses both the legal and technical dimensions of OHS, as well as the complexity of human and organizational factors.

Building on these technological advances, this study examines how Bird's Pyramid, the 5M Method, and the Weighted Composite Score (WCS) algorithm can improve OHS practices. The purpose of this article is to propose a weighted composite algorithm for occupational risk assessment as an alternative to the traditional method based solely on the product of severity and probability. By integrating additional relevant factors—frequency of exposure, number of exposed individuals, organizational response capacity, and incident history—the article aims to provide a more realistic, contextualized, and operational model for risk prioritization. It also demonstrates the alignment of this approach with the principles of ISO 45001 and highlights its strategic utility in supporting prevention and protection decision making at the organizational level.

1.1. History and Genesis of ISO 45001

The protection of employees' health and safety has continuously adapted to the changing conditions and types of work [21]. In antiquity, working conditions were governed by traditions and simple norms, focus on survival and accident prevention. Over time, occupational health and safety evolved alongside industrial development and the growing awareness of workplace risks [22].

In ancient times, civilizations such as Egypt, Mesopotamia, and Rome applied rudimentary norms and traditions in workshops and mines, focusing mainly on survival, hygiene, and rest periods [23–25]. During the Middle Ages (5th–15th centuries), work was organized through guilds and small workshops, where internal rules and craftsmen's responsibility provided basic protection despite the absence of legislation [26].

The Industrial Revolution marked a turning point, as rapid industrial expansion generated unsafe conditions with exposure to toxic substances, accidents, and occupational diseases. Worker protection was minimal, with limited institutional response [27].

In the 19th century the first legislative frameworks emerged, such as the Factory Act of 1833 in the United Kingdom, which introduced minimum standards for working conditions [28,29]. At the same time, the labor movement played a central role in advocating for shorter working hours, protective measures, and compensation laying the foundation-of modern [30].

Throughout the 20th century, occupational health and safety regulations expanded globally. Governments introduced laws requiring safe conditions, risk management, and training, institutionalizing occupational health and safety (OHS) practices [31]. At the international level the International Labour Organization (ILO) promoted conventions and recommendations serving as global benchmarks. In parallel, standards such as OHSAS 18001 and ISO 45001 established systematic frameworks for effective OHS management and continuous improvement [32,33].

In the contemporary context, priorities focus on proactive risk integrating safety into organizational culture, and addressing emerging hazards through research, regulations, and awareness campaigns [34]. This historical overview highlights how occupational health and safety has progressed from basic survival practices to comprehensive international standards, reflecting society's continuous commitment to protecting workers.

1.2. Risk Management Under ISO 9001, 31000, and 45001

Risk management is a key element in ensuring organizational performance and is explicitly integrated into both the ISO 9001:2015 standard for quality management and ISO 45001:2018 for OHS management. Although these standards target different areas, they share fundamental principles based on risk-based thinking, as a proactive method for preventing nonconformities, accidents, and failure to meet objectives [35].

ISO 9001:2015 promotes a process-based approach integrated with risk-based thinking, where risk is present in all activities and processes that may affect product quality or customer satisfaction [36]. Risks and opportunities must be identified, evaluated, and addressed at every stage—from planning to operation, evaluation, and improvement [37].

Similarly, ISO 45001:2018 builds the entire OHS management system on the identification of hazards and risk assessment in the workplace, promoting the prevention of accidents and occupational illnesses [8].

Common points between ISO 9001 and ISO 45001 regarding risk management include: integration of risk-based thinking in decision making and strategic planning; the need to establish clear, relevant objectives in relation to which risks are identified and assessed; consideration of risks as both negative (threats) and positive (opportunities); allocation of adequate resources for risk prevention and control; continuous monitoring of the effectiveness of actions taken and system improvement through the PDCA (Plan–Do–Check–Act) cycle.

Thus, both standards support the development of a robust, adaptive management system where risk is no just a threat but a component of progress and continuous improvement. Implementing a coherent risk management framework aligned with ISO 31000, organizations can integrate quality, health, and safety standards—building sustainability and resilience [38,39].

In this context, the critical role of a well-structured Safety Management System (SMS) in industrial corporations has been widely recognized. Historical accident data and case studies emphasize that effective corporate management, strong leadership, and a robust safety culture are central to achieving high safety performance, promoting a collaborative workplace, and supporting sustainable development. Practical tools, such as checklist-based self-assessments and quantitative evaluation indicators, help organizations assess and enhance managerial contributions to safety, reduce human-related risks, and advance toward Safety 4.0 practices [40]. Moreover, managing Occupational Health and Safety (OHS) is increasingly challenging for small enterprises (SEs), which often lack systematic risk assessment models. Recent research has proposed an integrated approach combining Fuzzy Analytic Hierarchy Process (FAHP) and Fuzzy Inference System (FIS) to develop a comprehensive OHS risk assessment framework. This model allows the evaluation of multiple criteria and sub-criteria, generating risk scores that help identify high- and moderate-risk enterprises. Implemented in five small enterprises in Bangladesh, the model demonstrated its practical utility in supporting safety professionals and managers in designing effective workplace health and safety strategies and programs [41].

In this dynamic context, ISO 31000 establishes the theoretical and practical foundations for a risk management system, offering principles, frameworks, and processes that are universally applicable to any type of organization. It defines risk not merely as a threat but as the effect of uncertainty on objectives, implying a dual approach: identifying hazards and leveraging opportunities. From this perspective, risk becomes a source of competitive advantage when managed effectively [38].

In implementing these standards, several converging principles emerge that are essential for building an integrated risk management system:

- Contextualizing risk: Understanding risk in relation to organizational objectives and specificities (according to ISO 31000) allows for the customization of control measures based on impact and likelihood.
- Collective participation: From top management to operational staff, the involvement of all stakeholders is crucial for fostering an organizational culture centered on prevention.
- Continuous monitoring and review: Any risk management system must include dynamic mechanisms for analysis and recalibration, in line with the PDCA (Plan–Do–Check–Act) cycle.

- Systemic integration: Risk is not a separate dimension but an integral part of all organizational subsystems—quality, environment, health, safety, information security, etc.

Therefore, the synchronized implementation of ISO 9001, ISO 45001, and ISO 31000 enables the shift from a fragmented compliance model to a unified one focused on organizational resilience. This model not only minimizes losses caused by incidents, nonconformities, or accidents but also optimizes decision making and resource use through anticipation, adaptability, and continuous learning [42].

Organizations that adopt an integrated approach to risk become better equipped to navigate change, protect human resources, and deliver sustainable added value to all stakeholders.

1.3. OHSAS 18001 to ISO 45001: Transition and Relevance

Organizations previously operated under the requirements of the OHSAS 18001:2007 standard, which was an important benchmark for implementing and maintaining an OHSMS. However, with the advent of the international standard ISO 45001:2018, there was a clear need to adapt to the new requirements, which provide a more integrated and systematic framework for managing occupational health and safety risks and opportunities [43].

The transition to ISO 45001 was driven by several factors relevant to the organization:

- Risk and opportunity-based approach: ISO 45001 encourages proactive risk management, as well as the identification and exploitation of opportunities for continuous improvement of OHS performance, beyond mere compliance with legal regulations.
- Integration with other ISO standards: ISO 45001 uses the High-Level Structure (HLS), which facilitates its integration with other management systems such as ISO 9001 (quality) and ISO 14001 (environment). This allows the organization to streamline its processes and resources.
- Active involvement of interested parties: The new approach emphasizes the participation and consultation of employees and other stakeholders in OHS processes, contributing to the creation of a safer working environment and reducing accidents and occupational diseases.
- Alignment with current legislative and social requirements: ISO 45001 better addresses the new legislative and social expectations regarding organizational responsibility towards employee health and safety.

For the studied organization, this transition was not just a simple change in standard but an important strategic step towards strengthening an organizational culture focused on employee health and safety. By adopting ISO 45001, the organization aimed to implement a modern management system with an integrated approach that genuinely supports risk prevention and promotes a safe and healthy work environment [44].

Thus, the transition to ISO 45001 provided a more robust and flexible framework for managing OHS, in line with international best practices and the specific requirements of its field of activity, facilitating sustainable long-term performance.

Table 1 offers a comparative analysis of the OHSAS 18001 and ISO 45001 standards, highlighting their key differences and improvements.

ISO 45001 represents a significant evolution from OHSAS 18001, shifting the focus from a reactive and technical approach to a strategic, proactive, and integrated one. This contributes to better integration of health and safety into the organizational culture and the overall management system [44].

Compared to the previous approach centered on controlling physical hazards and documentation compliance under OHSAS 18001, ISO 45001 adds value by emphasizing leadership, employee participation, and opportunity management. These elements are reflected in risk analysis through the introduction of factors such as frequency, nature of work, and incident history—elements correlated with organizational culture and OHS performance.

Table 1. Comparison of the OHSAS 18001 vs. ISO 45001 standards.

Category	OHSAS 18001	ISO 45001
Issuing body	BSI (British Standards Institution)	ISO (International Organization for Standardization)
Structure	Based on the old structure of management system standards (does not use Annex SL).	Based on Annex SL—a common structure for ISO management system standards (e.g., ISO 9001, ISO 14001).
Integration with other ISO standards	Limited. Difficult integration with other standards (different structures and terminologies).	Easy integration due to common structure–easily integrated with ISO 9001 and ISO 14001.
Risk approach	Focus on identifying risks and controlling them	Extends to identifying opportunities and improving OHS performance. Proactive approach to risks and opportunities, focused on prevention.
Employee participation	Implicit, indirect participation, limited to consultation	Active, explicit participation (consultation and involvement). Active employee involvement at all stages of the OHS management system.
Organizational context	Does not require a formal analysis of context	Requires analysis of internal and external context relevant to OHS.
Role of management	Delegated responsibility (e.g., OHS representative)	Direct involvement of top management (leadership).
Organizational culture	Technical approach, less culture-oriented	Promotes a culture of prevention and health.
Leadership and OHS culture	Management's role is less emphasized	Leadership plays an active and central role in promoting OHS culture.
Hazard identification	Focuses on existing hazards	Includes proactive identification of potential hazards and opportunities for improvement.
Change management	Not explicitly provided	Includes clear requirements for risk assessment related to operational, technical, or organizational changes.
Supply chain	Few requirements regarding contractors and suppliers	Requires control and evaluation of OHS performance of relevant external parties (e.g., suppliers, subcontractors).
Process approach	Less emphasized	Clear emphasis on a process-based approach.
Proactive vs. reactive approach	Predominantly reactive (hazard control)	Proactive (risk and opportunity assessment).
Documentation	OHS manual and formal procedures required	More flexible: documentation based on "documented information".
Consultation and participation	Limited, through representatives	Extended to all workers, regardless of position.
Key terms	Hazard, risk, incident	Hazard, risk, opportunity, context, interested parties.

2. Applicative Study

Based on the context of workplace accidents in Romania, as well as European and global perspectives, the development of this work was guided by several research questions: Q1. How can Bird's Pyramid and the 5M Method be applied to effectively manage workplace health and safety (WHS) risks? Q2. How does the Weighted Composite Score (WCS) algorithm improve upon and compare with the classic risk assessment model? Q3. What benefits does the Composite WCS model provide over the Classic model in terms of risk identification and mitigation? Q4. What challenges or obstacles are associated with implementing these risk assessment methods in industrial environments?

2.1. Workplace Accident in Romania: European and Global Perspective

Workplace accidents represent one of the most serious challenges for the labor market, directly affecting workers' health and lives, as well as the productivity and sustainability of organizations [45]. In this context, Romania, together with other European countries and the international community, acknowledges the importance of implementing effective and well-structured occupational health and safety management systems (OHSMSs), such as the ISO 45001 standard.

Table 2 provides a comparative overview of workplace accidents and the adoption of occupational health and safety standards, based on the most recent data available.

Table 2. Comparative overview of workplace accidents and the implementation of occupational health and safety management systems (ISO 45001) at national, European, and global levels.

Aspect	Romania [46–48]	Europe Union [49]	Global [50]
Total Number of Reported Workplace Accidents	~270 per 100,000 workers/year	~1600 per 100,000 workers/year	7000 per 100,000 workers/year
Severe workplace accidents	~32.6‰ of cases (300/year)	Hundreds of thousands annually	Millions of serious accidents annually
Fatalities Due to Workplace Accidents	50–100/year (~0.5 per 100,000 workers)	~3600/year (~1.9 per 100,000 workers)	~2.3 million/year (~29 per 100,000 workers)
Sectors with Highest Incidence	Construction, industrial production, agriculture	Construction, transportation and storage, manufacturing industry, agriculture, forestry, and fishing.	Construction, agriculture, mining, heavy industry
Percentage of Serious Accidents Attributed to OHS Non-Compliance	~70%	~60–80%	~70–80%,
Common Causes of Accidents	Lack of training, non-use of PPE, non-compliance with OHS measures	Similar to Romania, with additional emphasis on work-related stress and unsafe conditions	Inadequate training, improper equipment, and hazardous working conditions
Need for an OHS Management System (ISO 45001)	Critical, for reducing accidents and ensuring legal compliance	A priority, in line with EU directives and occupational health policies	Essential, especially in multinational companies and high-risk sectors
Impact of ISO 45001 Implementation	Increased awareness and incident reduction through a systematic approach	Widely adopted in the EU, reducing risks and promoting a safety culture	Recognized as the leading global standard for reducing accidents and improving OHS performance

According to official data from the Territorial Labor Inspectorate from Romania and the annual report of the Ministry of Labor and Social Protection, Romania recorded 4862 workplace accidents in 2023, with a population of 17.943 million people over the age of 18. These figures underscore the urgent need for the implementation of a structured and proactive OHS management system, as prescribed by ISO 45001, which advocates a systematic approach to risk identification and control, alongside active engagement of all personnel in maintaining a safe working environment [48].

Across most countries, the primary causes of serious accidents remain consistent: inadequate training and education, insufficient or inappropriate protective equipment, and hazardous working conditions [51]. Higher-level preventive measures are proactive actions aimed at eliminating or reducing hazards at the source, including hazard elimination, substitution with safer alternatives, and workplace design to minimize or remove risks.

Statistical data clearly highlight the necessity of implementing occupational health and safety management systems that operate on proactive, systematic, and integrated principles within organizational processes. The international standard ISO 45001 provides a comprehensive framework for identifying, assessing, and controlling occupational risks, as well as for the active involvement of all personnel in creating and maintaining a safe working environment [8].

In Romania, the implementation of ISO 45001 is essential for aligning with legislative requirements and reducing workplace incidents. Equally important is the improvement of legal provisions to ensure the systematic reporting not only of severe incidents but also of minor accidents and near misses, which are often underreported. Such comprehensive reporting would enhance prevention strategies and strengthen the effectiveness of occupational health and safety management systems. At the European level, the widespread adoption of this standard supports the strengthening of a shared safety culture, thereby contributing to accident reduction and enhanced economic competitiveness. On a global scale, ISO 45001 is recognized and applied primarily in multinational companies and high-risk sectors, where social responsibility and legal compliance are key [52].

Romania records statistical patterns comparable to European and global. The apparently lower number and rate of accidents is largely due to national reporting practices, where only severe incidents are systematically reported to the authorities, while minor cases remain at organizational level. Nevertheless, the considerable number of severe accidents and fatalities underlines the need for consistent implementation of ISO 45001 requirements as a key tool for accident prevention and employee protection [53].

Risk analysis and assessment represent a fundamental component of the OHSMS, aiming to identify hazards, evaluate the risks associated with workplace activities, and implement prevention and protection measures, in accordance with ISO 45001 principles and national legislation, in order to ensure a safe, healthy, and efficient working environment.

OHS Risk Management is a crucial component in the legislative landscape of most countries and for any business. Existing harm reduction methodologies are primarily based on risk methodology, namely, reducing the consequences or the likelihood of harm. The implementation of the ISO 45001 standard involves establishing OHSMS within an organization.

2.2. Managing WHS Risks Based on Bird's Pyramid and the 5M Method

According to the adapted Bird Pyramid [54], for every fatal accident there are approximately 30 serious accidents, 300 minor accidents, 30,000 hazardous incidents, and 300,000 near-miss events. This pyramidal structure demonstrates that low-severity events serve as significant indicators of the overall safety level within an organization. Neglecting these early warning signals facilitates the accumulation of risk factors, thereby increasing the likelihood of severe accidents.

The practical relevance of Bird's Pyramid lies in its value for effective risk management, emphasizing the need for systematic reporting and documentation of all incidents, including those that may appear insignificant, the careful analysis of near-miss events as valuable sources of organizational learning, and the development of a proactive safety culture focused on prevention and continuous improvement.

Thus, Bird's model [55] highlights that preventing and controlling minor incidents has a direct impact on reducing the probability of serious accidents, positioning the pyramid as a strategic reference that supports the transition from a reactive to a preventive and systematic approach to workplace safety.

The cause of a workplace incident is defined as the set of practices, factors, and situations that contribute to the occurrence or aggravation of a hazard during operations, affecting equipment, materials, goods, or the working environment, and thereby endangering the health and safety of employees.

In identifying the causes that may lead to a potential risk, the cause-and-effect diagram is used, based on the 5M analysis and the "5 Whys" method.

Table 3 provides an example of hazard identification that may generate risks associated with occupational health and safety, using the Ishikawa diagram. The analysis enables the structuring of hazards according to the five M factors (Man, Machine, Method, Material, Medium) and their correlation with possible consequences and applicable preventive measures.

Table 3. 5M Factors–Hazards, Consequences, and Preventive Measures.

Factor (5M)	Hazards	Consequences	Preventive Measures
Man	Lack of training, fatigue, stress, not wearing PPE *	Workplace accidents, operational errors, risk of illness	Regular training, medical check-ups, supervision, stress reduction
Machine	Malfunctions, lack of guards, noise, vibrations	Cuts, crush injuries, burns, harmful exposures	Preventive maintenance, guards, signaling, use of PPE *
Method	Incorrect procedures, lack of instructions, poor organization	Accidents, accidental exposures, increased errors	Clear procedures, audits, continuous training
Material	Toxic substances, improper storage, dust/fumes	Poisoning, burns, fires, explosions, mechanical injuries	Clear labeling, use of PPE *, ventilation, protective equipment
Medium	Poor lighting, insufficient ventilation, extreme temperatures	Respiratory illnesses, occupational diseases, slips/falls	Environmental control, ergonomics, air conditioning, regular cleaning

* PPE—Personal Protective Equipment.

Table 3 provides a clear overview of the main hazards, potential consequences, and preventive measures associated with each factor analyzed using the 5M method. It facilitates the identification and management of workplace risks and supports the implementation of a proactive safety culture.

Example: Risk analysis of a slip accident in a warehouse.

This structure shows how each 5M category contributes to hazard identification, the assessment of potential consequences, and the determination of preventive measures, exactly as the Ishikawa diagram is applied in OHS.

Based on the hazards identified in Figure 1, potential consequences are determined, and preventive measures are proposed for each of the five M factors to ensure effective risk management in work activities (Table 4).

Table 4. Identification of Risk Factors and Preventive Actions Based on the 5M Approach.

Factor (5M)	Potential Consequences	Preventive Measures	Responsible	Frequency
Man	Slips, bruises	Training, signage, adherence to PPE *	Department Head	Monthly
Machine	Slips, falls	Regular inspections, maintenance, leak collection	Maintenance Technician	Weekly
Method	Falling objects, impacts	Standardized handling procedures	Logistics Manager	Continuous
Material	Slips, cuts	Package inspection, regular cleaning	Warehouse Operator	Daily
Medium	Slips, collisions with objects	Adequate lighting, warning systems	OHS Officer	Quarterly

* PPE—Personal Protective Equipment.

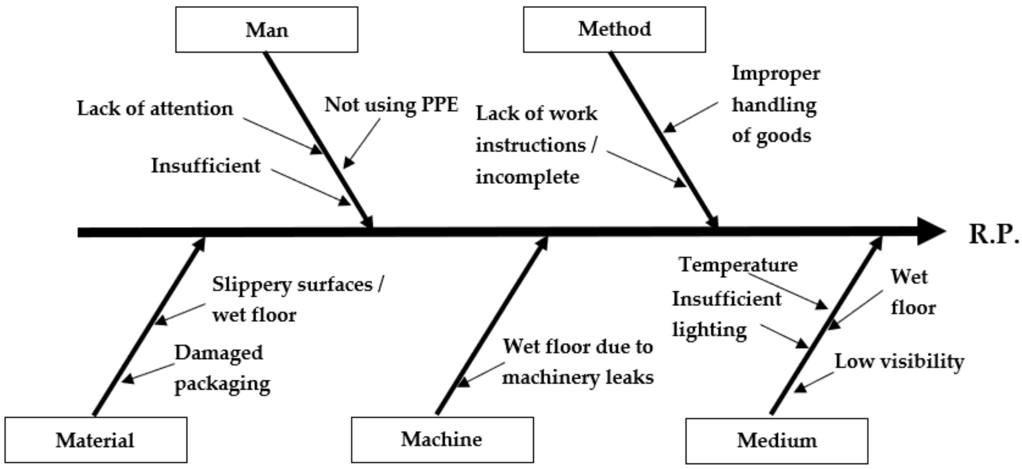

Figure 1. Identification of hazards that may impact OHS, using the Ishikawa diagram.

The integration of Bird's Pyramid and the 5M method as a means to identify workplace hazards supports a proactive safety culture and helps prevent accidents.

2.3. Occupational Risk Assessment: Classical Model

The case study was conducted in a production facility with a mixed industrial profile, encompassing mechanical, electrical, and logistics operations. The facility maintains an average of approximately 150 active employees per day, working in environments with varying degrees of occupational risk. The identified hazards include the operation of industrial machinery, handling of chemical substances, and the use of electrical equipment—each presenting specific potential threats to the safety and health of the workers.

Table 5 presents the occupational safety performance of the production unit over the last five years.

Table 5. Annual Safety Incidents and Risk Indicators (2021–2025) for the production unit.

Year	Total Incidents	Fatality	LTA *	NLTA **	Near Miss	Risky Situation
2021	131	1	0	5	45	80
2022	157	0	1	4	60	92
2023	207	0	0	4	92	111
2024	213	0	1	3	101	108
2025	203	0	0	2	98	103

Note: * LTA—Lost Time Accident; ** NLTA—Non-Lost Time Accident.

According to the presented data, there is a noticeable reduction in the severity of incidents, reflected by the absence of fatalities after 2021 and the very low number of lost-time accidents (LTAs). At the same time, an increase in the total number of incidents and reported situations, including near misses and risky situations, can be observed. This trend may indicate either a higher exposure of employees to occupational hazards or an improvement in the reporting and monitoring system of safety events.

Occupational risk assessment is a fundamental pillar of OHSMS, and conducting a comparative analysis between the classic methodology—based on the product of Severity × Probability—and a proposed weighted composite algorithm represents a solution for optimizing the assessment process and ensuring compliance with the requirements of the international ISO 45001 standard.

Table 6 presents the classical risk assessment, defining risk classes, their impact, and recommended control measures.

Table 6. Risk classes, impact, and control measures for the classical method.

Risk Class	Risk Range	Impact	Measures
Low	1–12	Minor	Minimal (training, warnings, etc.)
Medium	14–25	Significant	General control measures (visual management, training, medical checks, etc.)
High	30–42	Major	Specific (PPE, Lockout–Tagout techniques, etc.)

Tables 7–10 provide a summary of the risk assessment for occupational injuries and illnesses, adaptable to all workplaces within an organization, covering all components of the work system. The assessment was carried out using a standardized grid based on the combination of the severity class of consequences and the probability class of risk occurrence [56]. In accordance with the requirements of the OHSMS, risks are classified according to their main source: production means (technical execution); work environment; work task, and human factors (the worker). Each category is detailed in the corresponding tables, presenting the identified risk factors, specific manifestations, possible causes, maximum foreseeable consequences, severity class, probability class, and the associated risk level.

Table 7 identifies and evaluates risks generated by the use of technical production means, such as equipment and machinery, within the work process. Mechanical, thermal, electrical, and biological hazards are analyzed, along with their causes, consequences, and associated risk levels.

Table 7. Risk Analysis and Assessment Related to Production Means (Technical Execution).

Risk Category	Risk Factor	Risk Manifestation	Cause	Max Consequence	SC **	PC ***	Risk Level
Mechanical	Caught by built-in structural elements	Impact from structure	Inadequate signaling/lighting	TWI * (3–45 days)	2	2	4
Mechanical	Improperly stacked products	Crushing	Poor stacking	Death	7	2	14
Mechanical	Falling tools or parts being handled or transported	Injuries from falling objects	Improper cleaning	TWI (4–180 days)	3	3	9
Thermal	Exposure to open flame	Fire	Inadequate training	Death	7	2	14
Electrical	Electrocution	Contact with live electrical parts	Faulty wiring/ unprotected equipment	Death	7	1	7
Biological/ Behavioral	Aggression within premises	Physical harm	Conflicts, lack of control measures	TWI (45–180 days)	3	3	9

Note: * TWI—Temporary work incapacity; ** SC—Severity Class: 1—Negligible, 2—Minor (Marginal), 3—Medium (Severe), 4—Major I (High), 5—Major II (Serious), 6—Major III (Very serious), 7—Major IV (Critical); *** PC-Probability Class: 1—Extremely rare, 2—Very rare, 3—Rare, 4—Unlikely, 5—Likely, 6—Very likely.

Table 8. Risk Analysis and Assessment Related to the Work Environment.

Risk Category	Risk Factor	Risk Manifestation	Cause	Max Consequence	SC **	PC ***	Risk Level
Physical	Air currents	Discomfort, minor injuries	Inadequate training	TWI * (3–45 days)	2	4	8
Chemical	Gas exposure	Respiratory effects	Poor ventilation	TWI (3–45 days)	2	2	4
Chemical	Caustic cleaning solutions	Chemical burns	Improper cleaning	TWI (3–45 days)	2	4	8

Note: * TWI—Temporary work incapacity; ** SC—Severity Class; *** PC—Probability Class; The risk assessment scales used in the risk analysis to quantify the severity and probability of an unwanted event are the same as in Table 7.

Table 9. Risk Analysis and Assessment Related to the Work Task.

Risk Category	Risk Factor	Risk Manifestation	Cause	Max Consequence	SC **	PC ***	Risk Level
Inappropriate content	Storage of materials on access paths	Trip/obstruction	Inadequate training	TWI * (45–180 days)	3	3	9
Task mismatch	Performing untrained tasks	Severe injury/death	Lack of training	Death	7	1	7
Compliance failure	Non-compliance with OHS regulations regarding hazard exposure	Injuries	Lack of awareness	TWI (45–180 days)	3	3	9
Physical overload	Dynamic effort, atypical work cycle	Strain injuries	Improper workload	TWI (3–45 days)	2	2	4
Psychological overload	Time pressure/management pressure	Stress	Poor work planning	TWI (3–45 days)	2	3	6

Note: * TWI—Temporary work incapacity; ** SC—Severity Class; *** PC—Probability Class; The risk assessment scales used in the risk analysis to quantify the severity and probability of an unwanted event are the same as in Table 7.

Table 10. Risk Analysis and Assessment Related to the Worker (Human Factors).

Risk Category	Risk Factor	Risk Manifestation	Cause	Max Consequence	SC **	PC ***	Risk Level
Physiological	Fatigue/lack of sleep	Decreased attention, execution errors, increased reaction time	Long working hours, lack of breaks, night shifts	TWI * (45–180 days)/death	7	4	28
Psychological	Work-related stress	Hasty decisions, cognitive errors, decreased ability to concentrate	Pressure of deadlines, overload, lack of managerial support	TWI (45–180 days)	7	4	28
Psychological	Burnout/demotivation	Neglect of procedures, low involvement	Constant overwork, lack of recognition for performance	TWI (45–180 days)	3	3	9
Physiological/biological	Medical conditions (heart disease, diabetes, etc.)	Temporary loss of working capacity, fainting, sudden incapacity	Lack of regular medical check-ups, ignorance of individual limitations	Death	2	5	10
Cognitive	Lack of attention	Failure to notice warning signs, ignoring details	Monotony, repetitive tasks, sensory overload	TWI (45–180 days)	7	3	21
Competence	Lack of knowledge of procedures/lack of training	Incorrect use of equipment, dangerous handling	Insufficient training, lack of professional certification	TWI (45–180 days)	3	4	12
Behavioural	Violation of rules	Lack of PPE, dangerous improvisations, risky behaviour	"It won't happen to me" attitude, time pressure	TWI (45–180 days)/death	3	5	15
Organisational	Poor communication	Incomplete or incorrect transmission of information	Lack of briefings and feedback, unclear procedures	TWI (45–180 days)	3	4	12
Organisational/social	Lack of safety culture	Failure to report minor incidents, tolerance of misconduct	Passive leadership, lack of prevention policies	TWI (45–180 days)/death	2	5	10

Note: * TWI—Temporary work incapacity; ** SC—Severity Class; *** PC—Probability Class; The risk assessment scales used in the risk analysis to quantify the severity and probability of an unwanted event are the same as in Table 7.

Table 8 highlights physical and chemical risk factors present in the environment where workers carry out their activities (air currents, ozone, chemical substances). It details their forms of manifestation, causes, consequences, and the assessment of the associated risks.

This section analyzes the risks arising from how work tasks are designed and executed. It includes inappropriate work content, physical and mental overload, and their impact on worker safety.

Table 10 identifies human errors (wrong actions and omissions) as risk factors in the work process. It analyzes inappropriate behaviors, lack of training or attention, and the associated consequences. Additionally, Table 11 presents a prevention and protection plan specifically targeting the risk of electrocution, including technical and organizational measures aimed at reducing or eliminating this risk, in line with best practices and legal requirements.

Table 11. Prevention and Protection Plan in Case of Electrocution.

Evaluated Risk	Technical Measure	Organizational Measure
Direct contact–live parts, open panels, etc.	Insulation, enclosures, personal protective equipment (PPE)	Authorized personnel only, disconnect before work, PPE usage
Indirect contact–energized casings, no short-circuit protection	-Grounding, double insulation	Disconnect before repair, PPE, supervised interventions

Table 11 presents specific technical and organizational measures for preventing the risk of electrocution, both through direct and indirect contact. It includes solutions such as equipment insulation, use of personal protective equipment (PPE), and safe working procedures, especially applicable to activities involving electrical installations.

2.4. New Risk Assessment Structure

We proposed an exploratory conceptual framework—the Weighted Composite Score (WCS)—which integrates not only severity and probability but also operational and organizational dimensions (frequency of exposure, extent of workforce exposed, organizational response capacity, and history data).

The WCS model is presented as an illustration rather than a full validation, emphasizing its potential usefulness and the need for further empirical calibration:

$$\text{Weighted Composite Score, WCS} = (S \times P) \times (1 + F + N + R + H) \quad (1)$$

where S—severity (1–10), P—probability (1–10), F—frequency of exposure (0–5, dimensionless ordinal), N—extent of exposure (0–4, dimensionless ordinal), R—response/prevention capacity (-2 to +2, dimensionless ordinal; negative = strong measures, positive = weak measures), and H—incident history (0–5, dimensionless ordinal).

All parameters are expressed on normalized ordinal scales (dimensionless), ensuring mathematical consistency. In this formulation, F, N, R, and H act as influencers that adjust the baseline $S \times P$ score.

Table 12 presents the risk assessment based on the proposed composite algorithm, outlining the risk classes, their impacts, and the recommended control measures.

Table 12. Risk Classes, impact, and control measures for the composite algorithm.

Risk Class	Risk Range	Impact	Measures
Very Low	-1–30	Insignificant	Negligible, does not require special measures
Low	31–60	Minor	Monitoring and preventive measures
Moderate	61–100	Moderate	Continuous control measures
High	101–200	Significant	Specific measures and corrective actions
Very High	Over 201	Critical/Major	Urgent preventive measures and continuous monitoring

As part of the risk assessment using the composite algorithm, four additional variables were defined beyond the classic model ($S \times P$), in order to more accurately reflect the operational reality of the workplace. These variables are:

1. Frequency of exposure (F) variable reflects recurrence of the risk event, rated. It is rated on a scale from 0 to 5, based on the nature and recurrence of the activity: a value of 5 (Daily) is assigned to activities that occur every day, such as machine operation or repetitive manual handling; a value of 4 (Weekly) corresponds to tasks that happen regularly but not daily—these are recurring, such as weekly logistics operations; a value of 3 (Monthly) applies to periodic tasks, for example, monthly technical maintenance; a value of 2 (Quarterly) is used for occasional activities that take place once every few months; a value of 1 (Rare/Exceptional) represents very rare tasks performed only in special circumstances or emergencies; a value of 0 (None) is used for no accidents have occurred.

The model, while developed for a specific case, can also be applied to similar cases and adapted to the specific characteristics of each context, with numerical results adjusted accordingly.

Example: For the risk of falling objects in the logistics area (e.g., pallet handling), the frequency was rated 4, as these operations are performed on a weekly basis in a continuous flow.

2. Extent of exposure (N) variable indicates workforce potentially. It is assessed on a scale from 0 to 4.

Example: For the risk of electric shock, N was rated as 1 (only technical team).

Note: N could also be embedded into S, since broader exposure increases severity. However, we separate them to explicitly distinguish individual injury severity (S) from workforce exposure extent (N).

3. The Response capacity (R) variable: Revised to cover both protection and prevention. Rated −2 (excellent) to +2 (deficient). Example: Electric shock = −1 due to PPE and procedures.

4. The Incident history (H) variable takes into account past events related to the analyzed risk. It was assessed using accident records, incident reporting forms, and interviews with (OHS) personnel. Incident history is rated on a scale from 0 to 5, based on the severity and frequency of previous events: a value of 0 indicates no reported incidents; 1 corresponds to minor events with negligible consequences; 2 reflects one to two moderate incidents; values between 3 and 5 indicate repeated or severe incidents.

Example: For the risk of falling objects, a minor incident was recorded in the previous year (resulting in a superficial injury), so H was rated as 1.

To illustrate the contrast, we compared results obtained using both the classical and WCS models. Table 13 presents ranking by WCS, showing differences in prioritization.

Table 13. Ranking of Workplace Risk Factors by WCS vs. Classical Method (dimensionless index).

Rank	No.	Category	Description	S	P	Classical	F	N	R	H	WCS
1	1	Mechanical	Crushing or pinching by unstaked products	9	2	18	4	3	0	2	180
2	9	Inappropriate content	Non-compliance with OHS regulations	5	3	15	3	3	2	2	165
3	10	Omissions	Omission of safety measures	4	3	12	3	2	2	1	108
4	2	Thermal	Exposure to open flames	7	2	14	3	2	0	1	98
5	8	Incorrect actions	Unplanned operations	4	3	12	3	2	1	1	96
6	3	Mechanical	Falling tools	7	2	14	3	1	0	1	84
7	4	Incorrect actions	Falling	6	2	12	3	2	0	1	84
8	5	Physical	Air drafts	2	3	6	5	3	2	1	72
9	6	Chemical	Caustic solutions	6	2	12	2	2	0	1	72
10	7	Inappropriate content	Materials blocking access paths	3	3	9	4	2	0	1	72

Note: Classical method—kept for comparison; WCS is the composite index (dimensionless); Three risks have the same WCS (72) in this example; the order between them can be defined using a tiebreaker (e.g., H or estimated cost).

The table illustrates how the prioritization of workplace risk factors changes when using the WCS composite index versus the classical method. Differences in ranking reflect the impact of weighting and scoring criteria applied in the WCS approach, highlighting risks that have been re-prioritized.

The highest-scoring risk—crushing or pinching by unstaked products (score 18)—represents a serious and frequent hazard with documented historical incidents. This underscores the urgent need for both technical interventions (such as proper stacking and designated storage areas) and organizational measures (including handling procedures and targeted training). Notably, organizational risks like unplanned operations and omission of safety measures also scored highly, highlighting the vital role of organizational culture and ongoing training in preventing accidents.

This approach enables objective prioritization of risks based on a clear numerical index, easily comparable across different activities or hazard types. Integration of contextual factors, such as the number of exposed individuals or the presence of already implemented mitigation measures, provides a realistic view of the current risk level. Consideration of incident history (H) as a corrective factor directly reflects operational realities and field trends.

This methodology directly aligns with the principles promoted by ISO 45001, which emphasizes a systematic approach to risks and opportunities through a comprehensive, multidimensional risk assessment—not limited to consequences or probability alone. Integration of risks into organizational processes means the composite score offers an operational tool that can be correlated with performance indicators, prevention plans, and occupational safety investments. Continuous improvement is enabled, as data can be periodically updated, allowing for monitoring risk evolution over time and adjusting preventive measures accordingly. Therefore, the use of the composite score is not merely a classification technique but a strategic occupational health and safety management tool, aligned with the requirements and philosophy of ISO 45001, which calls for a holistic and proactive vision of workplace safety.

The analysis results, ranked in descending order by composite score, enabled identification of the most critical risks—such as electrocution or unauthorized operations—and provide a foundation for developing a prevention and protection plan with clear priorities focused on technical, organizational, and educational interventions.

To illustrate the comparative application of the two risk assessment methods, two representative risk types were selected:

Risk 1: Electric shock through direct contact.

Risk 2: Falling objects from height.

(a) Assessment Using the Classical Method (S × P)

The classical risk assessment model involves calculating the risk score by multiplying two factors: S = Severity of consequences (scale: 1–minimal, 10–fatal) and P = Probability of occurrence (scale: 1–unlikely, 10–inevitable).

Risk 1: S = 7 (potentially fatal accidents) and P = 1 (strong protection measures) → Risk Score: $R = 7 \times 1 = 7$.

Risk 2: S = 6 (moderate to severe trauma) and P = 2 (partially controlled conditions) → Risk Score: $R = 6 \times 2 = 12$.

(b) Assessment Using the WCS

Risk 1: S = 7, P = 1, F = 3, N = 1, R = −1 and H = 2 → Score: $(7 \times 1) \times (1 + 3 + 1 - 1 + 2) = 7 \times 6 = 42$.

Risk 2: S = 6, P = 2, F = 4, N = 3, R = −1 and H = 1 → Score: $(6 \times 2) \times (1 + 4 + 3 - 1 + 1) = 12 \times 8 = 96$.

As shown in Table 14, the composite model provides a much more realistic picture of the risk level by taking into account essential operational factors. The classical model tends to underestimate risks in dynamic industrial environments like the one analyzed.

Table 14. Comparative analysis of the assessment results for the two case examples.

Risk Type	Classical Score	Composite Score	Difference	Key Observation
Electric Shock	7	42	+35	Classical model significantly underestimates
Falling Objects from Height	12	96	+84	Frequent exposure increases real risk level

The application of the composite algorithm contributes to the transition from a reactive to a proactive approach, allowing continuous adjustment of prevention plans based on real data and the dynamics of risks in the field.

To assess the robustness and relevance of the proposed WCS model, a sensitivity analysis was carried out by varying each component parameter (S–severity, P–probability, F–exposure frequency, N–number of exposed persons, R–response capacity, and H–incident history) by ±1 unit.

We select a risk (ex: Falling objects from a height). The results of this analysis are presented in Table 15, which shows how the final WCS changes depending on parameter variations. It can be observed that the model is most sensitive to probability, followed by severity, while the operational variables (F, N, R, and H) influence the score to a moderate extent. This approach confirms that the proposed method allows the identification of critical factors and the proper prioritization of risks in the context of OHSMS and ISO 45001 principles.

Table 15. Simplified sensitivity analysis of the WCS model.

Modified Parameter	Initial Value	Modified Value (±1)	Applied WCS Formula	Resulting WCS	Difference From Initial (96)	Difference (%)
Severity (S)	6	7 (+1) 5 (−1)	(7 × 2) × 8 (5 × 2) × 8	112 80	+16 −16	+16.7% −16.7%
Probability (P)	2	3 (+1) 1 (−1)	(6 × 3) × 8 (6 × 1) × 8	144 48	+48 −48	+50.0% −50.0%
Frequency (F)	4	5 (+1) 3 (−1)	12 × (1 + 5 + 3 − 1 + 1 = 9) 12 × (1 + 3 + 3−1 + 1 = 7)	108 84	+12 −12	+12.5% −12.5%
Number of exposed persons (N)	3	4 (+1) 2 (−1)	12 × (1 + 4 + 4 − 1 + 1 = 9) 12 × (1 + 4 + 2 − 1 + 1 = 7)	108 84	+12 −12	+12.5% −12.5%
Response capacity (R)	−1	0 (+1) −2 (−1)	12 × (1 + 4 + 3 + 0 + 1 = 9) 12 × (1 + 4 + 3 − 2 + 1 = 7)	108 84	+12 −12	+12.5% −12.5%
Incident history (H)	1	2 (+1) 0 (−1)	12 × (1 + 4 + 3 − 1 + 2 = 9) 12 × (1 + 4 + 3 − 1 + 0 = 7)	108 84	+12 −12	+12.5% −12.5%

Note: The initial WCS is 96, calculated using the formula: WCS = (S × P) × (1 + F + N + R + H), where, for the analyzed case, the chosen values were: S = 6, P = 2, F = 4, N = 3, R = −1, H = 1.

The simplified sensitivity analysis highlights that the Weighted Composite Score (WCS) model reacts differently to variations in its input parameters. The results show that probability is the most influential factor, as a ±1 variation changes the score by ±50%. Severity also has a significant impact (±16.7%), while the operational parameters–exposure frequency (F), number of exposed persons (N), response capacity (R), and incident history (H)–have a more moderate but consistent effect (±12.5%).

This pattern indicates that the model places strong emphasis on the likelihood of occurrence and the potential severity of incidents while still accounting for contextual and organizational factors. Such a structure supports effective risk prioritization in line with OHSMS and ISO 45001 principles, ensuring that critical hazards are identified and addressed first, while operational factors refine the overall risk evaluation.

While some parameters of the WCS model (e.g., Response capacity, Incident history) involve subjective evaluation, the influence of Probability and Severity on the WCS is largely objective and can be applied across different contexts. The approach can be extended by adapting context-specific parameters and incorporating empirical data, allowing the model to support risk prioritization and decision making in various real-world applications.

However, it should still be noted that the simplified sensitivity analysis (Table 15) shows that Probability and Severity have the strongest impact on the WCS. This analysis is limited to the studied context and may be extended in future research to broader applications.

3. Discussion

Effective occupational health and safety management can protect and improve occupational health and safety in any company or institution. It helps plan and implement holistic policies to ensure that employees work in a healthy and safe manner [57]. Drawing upon on this foundation, occupational risks affect not only employee safety but also the stability and performance of companies. However, these risks can be effectively managed through a health and safety management system, and standards such as OHSAS 18001 and ISO 45001 provide a preferred framework for organizations seeking to demonstrate social responsibility and enhance their corporate image in a globalized economy [58].

In line with these standards, the ISO 45001 framework is recognized for its comprehensive approach to occupational health and safety management. Its flexible, high-level structure allows applicability across industries [59]. Consequently, risk analysis models must be tailored to meet the unique requirements of each organization while maintaining alignment with the overarching principles of ISO 45001. In this context, sensitivity analysis plays a crucial role in ensuring the reliability and robustness of such models. Saltelli et al. [60] emphasize the importance of sensitivity analysis as an essential component of good modeling practices and its implicit role across all fields of modeling. The authors argue that sensitivity analysis impacts the entire causal assessment chain, from data collection to predictions while also clarifying the influence of source uncertainties and formulation assumptions on model outcomes. This allows modelers to identify which variables or assumptions most significantly affect results and to prioritize efforts to reduce uncertainty. To illustrate this application, the proposed occupational health and safety analysis system for the healthcare sector aligns safety regulations with technological advances, allowing for the effective identification of the root causes of workplace incidents and preventing their recurrence. The model ensures full compliance with current legislation while emphasizing practical applicability, sustainability, and ease of use for all stakeholders. Moreover, by encouraging active participation, it fosters a culture of safety and can adapt to changes in workforce size, operational requirements, and workplace dynamics.

The necessity of establishing a well-defined Safety Management System (SMS) in industry is widely supported by recent literature. Zhelev et al. [61] highlight that SMS implementation in healthcare significantly improves safety performance by providing structured procedures and clear responsibilities. Chatzoglou et al. [62] demonstrate that a formal Health and Safety Management System enhances organizational performance by systematically identifying and mitigating risks. In the construction sector, Yiu et al. [63] show that SMS adoption reduces accident rates and ensures compliance with regulatory requirements while overcoming obstacles related to organizational culture and resource allocation. Niu and Liu [64] emphasize that research on SMS frameworks identifies critical success factors, such as leadership commitment, continuous monitoring, and integration with operational processes, which are essential for effective risk management. Finally, Saleem and Malik [65] illustrate that a robust SMS fosters a positive safety climate and raises safety consciousness among employees, directly linking system implementation to improved safety outcomes [5]. Collectively, these studies underline that a well-structured SMS is not only a regulatory requirement but also a strategic tool to enhance safety, reduce incidents, and promote a culture of continuous improvement in industrial environments.

On another note, Deng et al. [66] show that a favorable safety climate leads to more effective safety behaviors and a reduction in workplace accidents. A strong safety culture is associated with better occupational health and safety performance and with fewer workplace accidents [67]. A strong safety culture is associated with better occupational health and safety performance and with fewer workplace accidents [68].

Brandhorst and Kluge [69] indicate in their experiment that clear procedures and rules are fundamental for ensuring proper safety behavior. However, their effectiveness depends on implementation and employee compliance. Margheritti et al. [70] show that lack of resources can limit the effectiveness of safety measures and increase the risk of accidents. At the same time, management commitment is a key factor in the success of OHS initiatives. Dedicated management can positively influence organizational culture and employees' safety behaviors [71]. Employee motivation through factors such as rewards, recognition, and active engagement can encourage compliance with safety rules [72].

Beyond traditional approaches, modern risk methods are increasingly integrated with intelligent estimation techniques to improve safety in industrial settings. For instance, the proportional–fuzzy risk assessment technique (PRAT) applies fuzzy logic to factors such as probability, frequency, and severity, thereby enhancing accuracy and interpretability [73,74].

In addition, several well-established risk assessment methods exist, including FMEA, Bow-Tie Analysis, Fuzzy Logic, and Bayesian Networks. However, research on occupational risk evaluation from a human factors perspective mainly focuses on fuzzy logic and neural network techniques, applied according to the amount of data available [75]. FMEA ranks risks by severity, occurrence, and detectability [76]; Bow-Tie visualizes hazard pathways and control measures [77]; Fuzzy Logic handles uncertainty and subjective judgments [78]; and Bayesian Networks model causal relationships for probabilistic risk prediction [79].

The Weighted Composite Score (WCS) does not replace these approaches but provides a simpler, practical alternative, particularly suitable for small and medium-sized organizations with limited resources. By integrating key factors such as severity, probability, exposure, workforce, response capacity, and incident history, WCS enables quick and actionable risk prioritization, serving as an effective first-level screening tool while remaining aligned with ISO 45001 principles.

Supporting this perspective, in the specialized literature [80], risk evaluation based on the product of severity and probability is widespread and is employed in established standards and methodologies such as ISO 31000 and Failure Mode and Effects Analysis (FMEA) [81]. Pillay and Wang [82] propose an innovative risk analysis method for the maritime industry, combining FMEA with failure analysis and laboratory risk assessment, utilizing fuzzy logic and grey relational theories. The method is based on three key factors—probability, severity, and detectability—and is capable of operating effectively even under uncertainty or with limited data. Highlighted advantages include identifying system weaknesses, integrating expert knowledge into the evaluation process, and efficiently classifying risks according to their level. Developing on these concepts, our proposed formula goes further by incorporating additional operational and contextual factors, including the effectiveness of control measures (−R) and a contextual adjustment coefficient (H), which allows adaptation to sector-specific hazards. Overall, the impact of ISO 45001 implementation on organizational performance underscores the necessity for holistic risk assessments that go beyond simplistic severity-probability calculations. The proposed formula of our study (1) addresses this need by integrating variables that provide a more comprehensive understanding of employee exposure and vulnerability, which are critical components in accordance with ISO 45001 principles.

Jääskeläinen et al. [53] highlight the importance of measuring safety performance using indicators that encompass both technical and organizational factors. The inclusion of the term−R in the formula accounts for the effectiveness of implemented control measures, aligning with recommendations for continuous monitoring and improvement of preventive processes.

Furthermore, the work of Madsen et al. [43] demonstrates that the successful implementation of standards such as OHSAS 18001 and ISO 45001 largely depends on tailoring the management system to the specific organizational context. Accordingly, the coefficient H within the formula can be interpreted as an adjustment factor for contextual elements, such as the nature of the activity or sector-specific hazards, an aspect often underrepresented in classical risk assessment methodologies.

Compared to traditional approaches where risks are assessed merely by multiplying severity and probability, this formula provides a more dynamic and flexible framework that supports decision making based on a deeper understanding of risks and their actual impact on the workforce.

The integration of additional factors into risk assessment, as proposed by the formula, reflects modern research directions in the field and aligns with ISO 45001 requirements, thereby contributing to more effective and context-specific occupational risk management.

This study makes an original contribution by developing and applying an extended occupational risk assessment formula that goes beyond the traditional severity × probability model by integrating additional essential variables, such as employee exposure levels, the effectiveness of control measures (−R), and a contextual adjustment coefficient (H) tailored to the specific characteristics of each sector. This approach enables a more detailed understanding of actual risks and supports informed decision making for prioritizing preventive actions. Moreover, the application of the WCS method in a mixed industrial environment demonstrates its potential to effectively identify and rank critical risks, contributing to alignment with ISO 45001 requirements regarding risk planning and continuous improvement of OHS performance. With its modular and adaptable structure, the proposed model provides a practical and sustainable framework for risk management, relevant not only to industrial organizations but also to complex sectors such as healthcare.

It should be noted that the WCS produces higher but relative values, and its primary purpose is to prioritize risks rather than provide a monetary cost or absolute frequency.

We acknowledge key limitations of the WCS model: (1) lack of empirical validation, (2) subjective assignment of scales, (3) partial overlap between parameters (e.g., S and N). Future work will include empirical calibration, expanded scales (covering people, property, and environment), and integration with quantitative datasets. Additionally, we recognize that effective OHS management critically depends on leadership commitment and employee engagement, which are central elements of organizational safety culture. Incorporating these human factors into future iterations of the WCS model could further strengthen proactive risk management and alignment with ISO 45001 principles. The present study is intended as a proof of concept to illustrate how contextual factors can enrich risk prioritization. The model was tested in a single case study, without extensive validation on multiple datasets, and the scores assigned to variables (S, P, F, N, R, H) are subjective, requiring further calibration using historical incident and accident data. The assignment of values for exposure frequency, response capacity, or incident history may vary between experts; therefore, inter-evaluator testing and adjustment of assessment guidelines are recommended to minimize this source of error.

The WCS model should be compared with traditional risk analysis approaches, such as FMEA, Bow-Tie, or the classic $S \times P$ matrix, to evaluate consistency and adjust scores in accordance with operational reality.

The WCS model constitutes an exploratory and strategic framework, providing a basis for prioritizing technical and organizational interventions, while empirical validation and continuous adjustment are essential to enhance its accuracy and applicability in practice, in line with ISO 45001 principles.

4. Conclusions

The implementation of the ISO 45001 standard within the analyzed organization revealed several major benefits for the management of OHS. One of the most significant advantages is the systematic identification of improvement opportunities that go beyond merely reducing risks. This approach enables the organization not only to prevent accidents and occupational diseases but also to optimize work processes and conditions, thereby enhancing overall performance and employee satisfaction.

Furthermore, the transition to ISO 45001 underscores the urgent need to update organizational culture. A health and safety culture should not be reactive, limited to responses after incidents occur but proactive, anticipating and managing risks continuously and integratively. This cultural shift requires a mindset oriented towards prevention, collaboration, and continuous learning, ensuring greater adaptability to changes in the work environment and emerging challenges.

The application of the WCS method in the analyzed manufacturing unit enabled a more accurate identification of critical risks and effective prioritization of preventive interventions. Key takeaways include: complementing the classic risk assessment method with contextual factors is highly recommended, especially in mixed industrial environments; the composite evaluation serves as a valuable tool for informed decision making regarding the allocation of safety resources, and implementing this model fosters continuous improvement of the organizational safety culture.

The proposed WCS model offers an integrative, semi-quantitative framework that overcomes certain shortcomings of the classical $S \times P$ approach. By including frequency, exposure, response capacity, and history, WCS provides a more realistic prioritization of risks. While exploratory and not yet fully validated, it aligns conceptually with ISO 45001's systemic approach and opens avenues for proactive safety management.

The proposed WCS method has some limitations. Certain parameters involve subjective judgment, and the confidence limits of the evaluation should be considered. Further validation using empirical data in diverse industrial contexts is necessary to ensure the robustness and generalizability of the approach.

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Abbreviations

The following abbreviations are used in this manuscript:

OHS	Occupational Safety and Health
OHSAS	Occupational Health and Safety Assessment Series
ILO	International Labour Organization
OHSMS	Occupational Health and Safety Management Systems
WCS	Weighted Composite Score

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