RESEARCH OF PROCEDURAL MODALITIES OF INVESTIGATING SAFETY INCIDENTS IN THE BUSINESS SYSTEM

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ORIGINAL SCIENTIFIC PAPER

Received: 07 Jun 2026.
Accepted: 31 October 2026.
Published: 16 November 2026.
DOI: https://doi.org/10.63395/STEDConf15022026131V427

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Citation: Vranješ, B., et al.; (2026). Research of procedural modalities of investigating safety incidents in the business system. In Kojić, D. & Sredić. D. (eds.) *Conference proceedings, XV XV International Conference on Social and Technological Development: STED 2026* (pp. 427-437). Trebinje, B&H: University PIM.

ABSTRACT

The goal of occupational safety is to protect employees from unfavorable working conditions in the working environment, i.e. from the consequences of the realization of the present dangers and harmful factors in the working environment, which are manifested in the form of injuries at work and occupational diseases. This is achieved by designing preventive measures for occupational safety in order to reduce to the smallest possible measure the risks for safety and health at work and by designing corrective measures for protection after the realization of incident situations. The choice and effectiveness of designing corrective measures in the field of occupational safety depends on the way of investigating incident situations and determining the cause, i.e. factors that led to the realization of such events.

This paper presents the research conducted in business entities of the region on the perception of the need to investigate incidents in the field of occupational safety, operational procedures for investigating such events, as well as possible consequences for the business system. Also, the factors that are the most common causes of incident events in the field of occupational safety were identified in order to improve the investigation procedures of these incidents through the design of corrective measures.

The improvement of the occupational safety system in the business system should go in the direction of building an adequate information system that will enable the monitoring of all relevant factors important for the occupational safety system. This approach should ensure a more efficient investigation of incidents in the field of occupational safety, identification of the causes of their occurrence, and the design of preventive and corrective measures. In conditions of accelerated development and use of information technologies and artificial intelligence in many areas, they also find their place in the field of occupational safety. The implementation of these technologies in occupational safety systems should contribute to the implementation and development of sustainable occupational safety systems, and within them new modalities of investigation of incident situations.

Keywords: occupational safety, incident situation, investigation.

INTRODUSTION

Occupational safety is a multidisciplinary and interdisciplinary scientific and professional field concerned with the study of the adverse effects of work and work processes on the safety and health of workers and, accordingly, with the design of appropriate protective measures. The implementation of occupational safety within a business system is achieved through the establishment and application of an occupational safety management system. Such a system constitutes an integral part of every business organization. Its functioning is ensured through the execution of processes and activities aimed at protecting workers in the workplace and the working environment. Occupational safety measures are designed to reduce the likelihood of risks arising from the presence of hazards and harmful factors in the working environment. The primary responsibility of the employer is to plan and organize the occupational safety system within the framework of business processes. This obligation is also regulated by occupational safety legislation. In all countries of the region, occupational safety regulations require employers to establish and maintain an effective occupational safety system. National legislative frameworks in the region are largely aligned with European legal standards, particularly those established by the general framework Directive 89/391/EEC, which lays down the fundamental principles for the introduction of measures aimed at improving the safety and health of workers at work [1]. The need for effective occupational safety management within business systems/organizations has led to the development of standards and best practice guidelines that provide recommendations for the protection of human resources through the enhancement of occupational safety and health. Standardization in the field of occupational safety management is primarily based on the implementation of the ISO 45001 standard. The ISO 45001 standard requires organizations that implement it to establish, apply, and maintain processes that include reporting, investigation, and corrective actions for the purpose of identifying, managing, and addressing incidents and nonconformities [2]. Processes related to incident response and the management of their consequences involve the implementation of appropriate measures and the effective control of resulting outcomes. Furthermore, the standard requires organizations to investigate incidents, determine their root causes, prevent their recurrence, implement corrective actions, and review risk assessments where necessary. It also emphasizes the involvement of all relevant stakeholders in these processes to ensure continuous improvement of the occupational safety management system.

In certain situations, despite the implementation of occupational safety measures, incident situations may still occur in the working environment. An incident is defined as an occurrence arising out of or in the course of work that could lead, or does lead, to injury or impairment of health [2]. The occurrence of incident situations, in order to fulfill the preventive role of occupational safety and reduce the likelihood of recurrence, requires a thorough investigation of such events. Incident investigation is a cause-and-effect activity because it is conducted after the occurrence of an undesirable event, which is subsequently analyzed and explained [3]. Furthermore, the investigation of occupational safety incidents is carried out with the objective of mitigating and remedying the consequences resulting from their occurrence. The consequences of

an accident or incident situation may manifest in various forms, including worker injuries, interruption of production and technological processes, and damage to material assets and natural resources [4].

The preventive role of the occupational safety system implies that the injury itself is of secondary importance, while the primary objective is to identify its causes in order to undertake appropriate preventive and corrective actions. The causes of occupational injuries are generally classified into two groups, although this classification is relative due to the complex interactions among these factors:

- causes in which the so-called subjective factor (human factor) predominates, relating to the characteristics and behavior of the worker;
- objective causes related to the level and duration of exposure to hazards and harmful factors, i.e., factors associated with the working environment, workplace conditions, and social environment [5].

Identifying the actual causes of incident situations or occupational injuries is often challenging because some factors that appear to be significant may not be the true causes. Instead, the underlying causes are frequently hidden due to insufficient expertise, lack of thorough analysis, subjective judgment by investigators, or because the injured worker and other individuals involved in the incident failed to provide relevant and accurate information. The procedure for investigating the hidden causes of occupational incidents and accidents involves the analysis of four key elements within the working environment – organization, workplace, human factors, and safety measures – as illustrated in Figure 1.

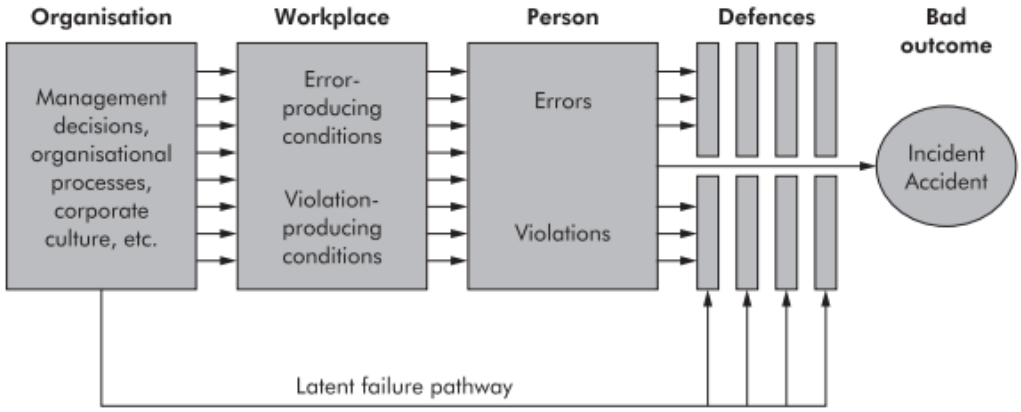


Figure 1. Reason's model of incident/accident stages [6].

Ultimately, the investigation of occupational safety incidents, through the development and implementation of preventive and corrective safety measures, should contribute to improvements in occupational safety management. In this context, procedures for investigating all incidents are of great importance, as they facilitate the clear identification of the root causes of hazardous events that may result in adverse consequences for workers, equipment, or the working environment [7]. An incident investigation procedure represents an established set of rules for conducting investigations through the application of specific methods aimed at determining the root causes of the occurrence of a harmful event. The procedure for investigating a harmful event should be presented in a format that is suitable both for occupational safety professionals and for all individuals involved in the investigation process [8].

At the current stage of information technology development and its increasingly widespread application across various fields, these technologies are also finding significant applications in the

field of occupational safety, particularly in the investigation of safety incidents. Artificial intelligence and natural language processing (NLP) systems show immense potential in processing and interpreting large datasets for risk analysis [9]. These technologies are key to automatically extracting critical factors from unstructured occupational accident reports, enabling the creation of structured datasets and faster identification of causal relationships [9]. By processing vast amounts of historical safety data, AI can discern patterns and correlations, predicting possible incidents and failure points before they occur [10]. This proactive approach allows for the implementation of preventative measures, reducing the likelihood of accidents and incidents [10].

METHODOLOGY SECTION

The objective of this research was to determine the existence of standardized operational procedures used in the investigation of occupational safety incidents. Furthermore, the research sought to examine whether the investigation of incident situations leads to changes in the management of occupational safety consequences and to identify the dominant factors contributing to the occurrence of incident situations in the field of occupational safety.

Hypothesis: Occupational safety incident situations generate consequences for the business system/organization and for the occupational safety management system.

The material used in this research consists of data collected through an online survey conducted among business systems, i.e., companies operating in the region. The survey gathered responses from 70 business entities from regional countries, excluding Slovenia: Croatia (5), Bosnia and Herzegovina (48), Serbia (14), Montenegro (2), and North Macedonia (1). The research was conducted during 2025.

In this research, the following variables were used: independent variables (*Business system/company/organization profile and Investigation of occupational safety incidents*) and the dependent variable (*Consequences of incident situations for the business system/company/organization*).

The measurement scale for the independent variable *Business system/company/organization profile* was composed of the following individual variables:

1. Number of employees
2. Business activity/industry sector
3. Ownership type
4. Job position.

The measurement scale for the independent variable *Investigation of occupational safety incidents* was composed of the following individual variables:

1. Operational procedures for incident investigation
2. Manifestations of incident occurrence
3. Occurrence of severe consequences resulting from incidents situations (serious or fatal occupational injuries)
4. Causal factors contributing to incident occurrence.

The measurement scale for the dependent variable *Consequences of incident situations for the business system/company/organization* was composed of the following individual variables:

1. Negative impact on organizational occupational safety objectives
2. Costs associated with mitigating the consequences of occupational incidents/accidents (direct and indirect costs)
3. Damage to the organization's reputation among employees
4. Damage to the organization's reputation among external stakeholders and customers.

Respondents evaluated the individual dependent variables using a five-point Likert scale, where the minimum score was 1 (Strongly Disagree) and the maximum score was 5 (Strongly Agree).

Microsoft Excel and the SPSS software package were used for statistical data processing and analysis. Descriptive and analytical statistical methods were applied using standard statistical indicators, including frequency, percentage, sum, arithmetic mean, standard deviation, median, Spearman's rank correlation coefficient, and the nonparametric Mann–Whitney U test.

RESULTS AND DISCUSION

The sample structure, in terms of frequencies for the independent variable *Businnes system/company/organization profile*, is presented as follows:

1. *Number of employees* (Up to 50 – 16%, From 50 to 200 – 17%, From 200 to 500 – 24%, From 500 to 1000 – 13%, and Over 1000 – 30%).
2. *Business activity/industry sector* (Production – 83%, Non-productive – 17%). Among companies engaged in production activities, the most represented sectors in the sample were: Energy (supply of electricity, gas, water, etc.) – 26%, Mining – 17%, and Other production activities – 14%. Among non-productive activities, the most represented sector was Health and social care – 9%.
3. *Ownership type* (State-owned – 24%, Private – 44%, Mixed ownership – 27%, and Other – 5%).
4. *Job position* (Member of the management board – 17%, Head of the occupational safety sector/departments/service – 40%, Occupational safety professionals – 29%, Employee knowledgeable in occupational safety – 10%, and Other – 4%).

The individual variables and the frequency distribution of the measurement scale for the independent variable *Investigation of occupational safety incidents* are presented in Figures 2–5.

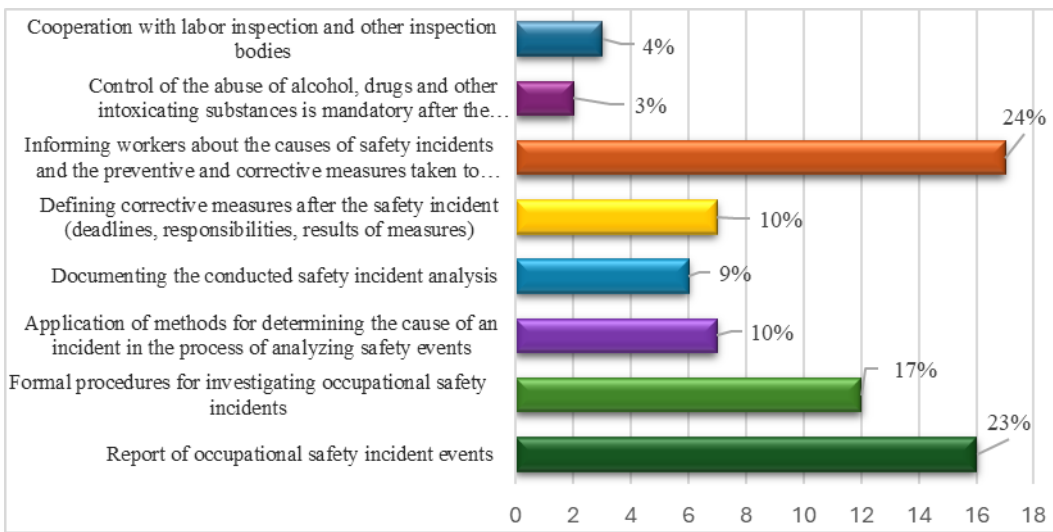


Figure 2. Operational procedures for incident investigation applied by the surveyed business systems/organizations

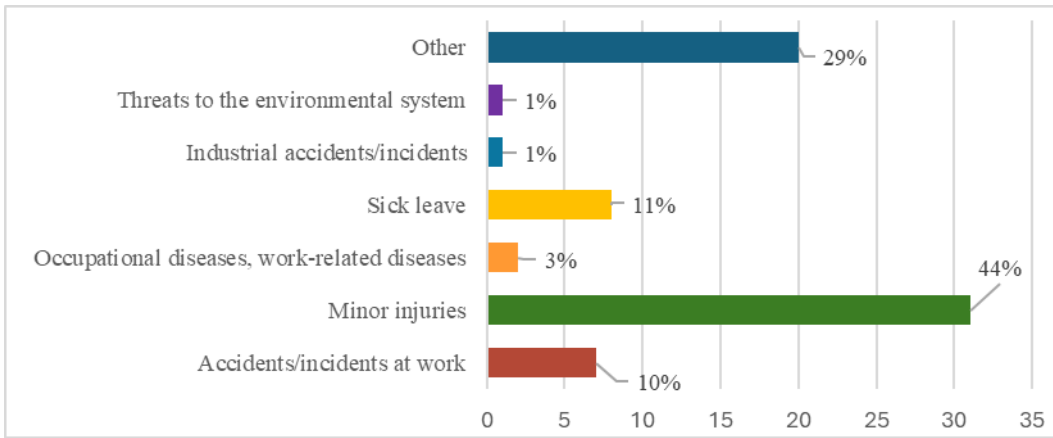


Figure 3. Manifestations of incident occurrence in the surveyed business systems/organizations

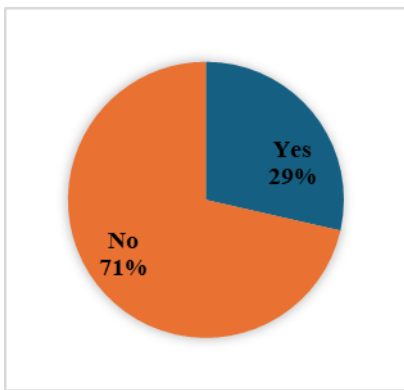


Figure 4. Occurrence of severe consequences resulting from incident situations (serious or fatal occupational injuries)

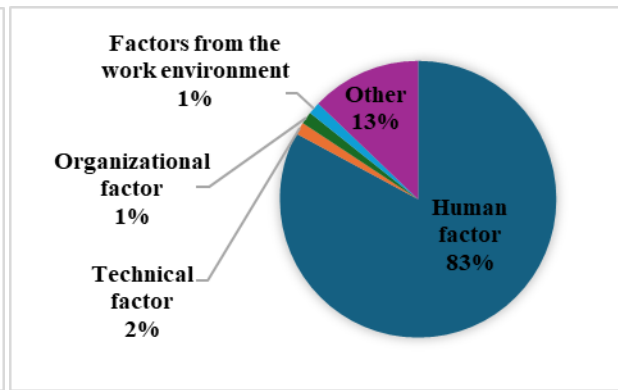


Figure 5. Causal factors contributing to incident occurrence

According to the presented results, various modalities and procedural approaches to the investigation of safety incidents, i.e., occupational safety incidents, are applied within the surveyed business systems/organizations. The most frequently implemented approaches are *Informing workers about the causes of safety incidents and the preventive and corrective measures taken to prevent similar events in the future* (24%), *Report of occupational safety incident events* (23%), and *Formal procedures for investigating occupational safety incidents* (17%), while other approaches are represented to a lesser extent.

The most common manifestation of occupational safety incidents in the surveyed business systems/organizations is minor occupational injuries, accounting for 44% of all reported cases. Furthermore, 71% of the surveyed business system/organizations reported that no severe consequences of safety breaches had occurred in the form of serious or fatal occupational injuries.

The research findings also identified the most significant causal factors contributing to the occurrence of incident situations. The human factor was identified as the dominant cause, accounting for 83% of all cases. Based on these findings, it can be concluded that the design of preventive and corrective occupational safety measures should primarily focus on addressing

human-related factors in order to reduce the occurrence of incident situations and improve overall workplace safety. The obtained results are also supported by findings reported in the literature regarding the dominant role of the human factor as a cause of occupational safety incidents. It is generally accepted that 80–90% of accidents are attributable to human error [11]. Human errors represent a dominant contributing factor in complex and high-risk systems [12]. A systematic review of the literature confirms that human errors and violations of established procedures are central factors contributing to industrial accidents [13].

The process of investigating incident situations and identifying the most significant causal factors, with particular emphasis on the human factor, increasingly involves the application of information technologies, including artificial intelligence, machine learning, and related technologies. The identification of root causes is of particular importance in high-risk industries, as it provides the basis for developing appropriate preventive and corrective measures aimed at addressing the identified causes of incident occurrence. In high-risk industries, artificial intelligence has been used to identify factors contributing to incident situations, with a particular focus on mapping human errors and unsafe behaviors [14]. By utilizing advanced machine learning algorithms, such systems can effectively analyze environmental conditions and personnel behavior in the period preceding an accident, thereby providing objective insights independent of investigator bias [14].

Table 1 presents the descriptive analysis (descriptive indicators: arithmetic mean and standard deviation) of the individual variables comprising the measurement scale of the dependent variable *Consequences of incident situations for the business system/company/organization*.

Table 1. Descriptive analysis of the individual variables comprising the measurement scale of the dependent variable *Consequences of incident situations for the business system/company/organization.*

Variables	Arithmetic mean	Standard deviation
Negative impact on organizational occupational safety objectives	3.84	1.05
Costs associated with mitigating the consequences of occupational incidents/accidents (direct and indirect costs)	3.90	0.99
Damage to the organization's reputation among employees	4.06	0.98
Damage to the organization's reputation among external stakeholders and customers	4.03	1.07
Total	3.96	1.02

The research results indicate that, according to the respondents/business systems/organizations, incident situations do have consequences, and these consequences were rated relatively highly (overall mean score = 3.96). However, the consequences for the organization are slightly more valued those for the occupational safety system within the organization, with the variable *Negative impact on organizational occupational safety objectives* receiving the lowest rating.

Correlation analysis was applied to determine the relationships between the variables, while the correlation coefficient was used to assess the strength and direction of these relationships. The correlations among the individual variables of the measurement scale *Investigation of occupational safety incidents* are presented in Table 2**.**

According to Spearman's interpretation of correlation coefficients, values ranging from 0.2 to 0.4 indicate a weak positive correlation, values from 0.4 to 0.7 indicate a moderate to significant positive correlation, and values from 0.7 to 1.0 indicate a high or very high positive correlation [15], [16].

Table 2. Correlation matrix of the variables comprising the measurement scale *Investigation of occupational safety incidents.*

Correlations			Investigation of occupational safety incidents
Spearman's rho	Operational procedures for incident investigation	Correlation Coefficient	.282*
		Sig. (2-tailed)	.018
		N	70
	Manifestations of incident occurrence	Correlation Coefficient	.554**
		Sig. (2-tailed)	.000
		N	70
	Occurrence of severe consequences resulting from incidents situations (serious or fatal occupational injuries)	Correlation Coefficient	.433**
		Sig. (2-tailed)	.000
		N	70
	Causal factors contributing to incident occurrence	Correlation Coefficient	.626**
		Sig. (2-tailed)	.000
		N	70
	Investigation of occupational safety incidents	Correlation Coefficient	1.000
		Sig. (2-tailed)	.
		N	70

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

The variables comprising the measurement scale *Investigation of occupational safety incidents* exhibited significant positive correlations (level of significance < 0,01), with the exception of the variable *Operational procedures for incident investigation*, which demonstrated a weak positive correlation (level of significance < 0,05). The strongest correlation was identified for the variable *Causal factors contributing to incident occurrence*, suggesting that the respondents/business systems/organizations consider the identification of causal factors to be the most influential component of the incident investigation process.

The correlations among the individual variables of the measurement scale *Consequences of incident situations for the business system/company/organization* are presented in Table 3.

All variables comprising the measurement scale *Consequences of incident situations for the business system/company/organization* exhibited high to very high positive correlations (level of significance < 0,01). Respondents/business systems/organizations who, on the scale *Negative impact on organizational occupational safety objectives*, give higher marks, to a statistically significantly greater extent, at the level of significance < 0.01, evaluate better the *Costs associated with mitigating the consequences of occupational incidents/accidents (direct and indirect costs)*, better assess *Damage to the organization's reputation among employees* and *Damage to the organization's reputation among external stakeholders and customers*, and better evaluate the *Consequences of incident situations for the business system/company/organization*. The strongest correlation was found on the variable *Damage to the organization's reputation among external stakeholders and customer*, followed by the variable *Negative impact on organizational occupational safety objectives*, which leads to the conclusion that the respondents/business systems/organizations believe that the consequences of incident situations for the business system/company/organization are most influenced by these two variables, i.e. the realization of incident situations creates consequences for the organization as a whole, but also affects the occupational safety system that has been established.

Table 3. Correlation matrix of the variables comprising the measurement scale *Consequences of incident situations for the business system/company/organization.*

Correlations			1	2	3	4	***Consequences of incident situations for the business system/company/organization***
Spearman's rho	1. *Negative impact on organizational occupational safety objectives*	Correlation Coefficient	1.000	.745**	.733**	.742**	.907**
		Sig. (2-tailed)	.	.000	.000	.000	.000
		N	70	70	70	70	70
	2. *Costs associated with mitigating the consequences of occupational incidents/accidents (direct and indirect costs)*	Correlation Coefficient	.745**	1.000	.693**	.758**	.890**
		Sig. (2-tailed)	.000	.	.000	.000	.000
		N	70	70	70	70	70
	3. *Damage to the organization's reputation among employees*	Correlation Coefficient	.733**	.693**	1.000	.820**	.878**
		Sig. (2-tailed)	.000	.000	.	.000	.000
		N	70	70	70	70	70
	4. *Damage to the organization's reputation among external stakeholders and customers*	Correlation Coefficient	.742**	.758**	.820**	1.000	.912**
		Sig. (2-tailed)	.000	.000	.000	.	.000
		N	70	70	70	70	70
	5. *Consequences of incident situations for the business system/company/organization*	Correlation Coefficient	.907**	.890**	.878**	.912**	1.000
		Sig. (2-tailed)	.000	.000	.000	.000	.
		N	70	70	70	70	70

**. Correlation is significant at the 0.01 level (2-tailed).

In order to determine whether the selection of an operational procedure influences the overall incident investigation process, i.e., whether statistically significant differences exist among the selected procedures, the nonparametric Mann–Whitney U test was applied. For the purposes of the analysis, all procedures were classified into two independent groups: 1. group (*Formal procedures for investigating occupational safety incidents; Application of methods for determining the cause of an incident in the process of analyzing safety events; Defining corrective measures after the safety incident (deadlines, responsibilities, results of measures); Informing workers about the causes of safety incidents and the preventive and corrective measures taken to prevent similar events in the future*) and 2. group (*Report of occupational safety incidents events*; *Documenting the conducted safety incident analysis*; *Control of the abuse of alcohol, drugs and other intoxicating substances is mandatory after the occurrence of an safety incident, Cooperation with labor inspection and other inspection bodies.*

The results of the Mann–Whitney U test (Table 4) indicate that there is a statistically significant difference between first and second groups procedures used in the investigation of incident situations.

The Mann–Whitney U test confirmed a significant difference between procedures 1. group ($Md = 6$, $n = 44$) and 2. group procedures ($Md = 7$, $n = 26$), $U = 384.500$, $z = -2.345$, $p = 0.019$, $r = 0.28$. The identified statistical difference indicates a moderate effect size (Pallant, 2009; Cohen, 1988).

The statistically significantly higher rank observed for 2. group investigation procedures suggests that business organizations more valued on incident reporting and documentation procedures, control of alcohol and substance abuse in connection with incident occurrences, and cooperation with inspection and regulatory authorities during the incident investigation process.

Table 4. Mann–Whitney U Test results for the variable *Investigation of occupational safety incidents*: Operational procedures for incident investigation.

Ranks				
	Operational procedures for incident investigation	**N**	**Mean Rank**	**Sum of Ranks**
Investigation of occupational safety incidents	1.group	44	31.24	1374.50
	2. group	26	42.71	1110.50
	Total	70		

Test Statistics[a]	
	Investigation of occupational safety incidents
Mann-Whitney U	384.500
Wilcoxon W	1374.500
Z	-2.345
Asymp. Sig. (2-tailed)	.019
a.Grouping Variable: Operational procedures for incident investigation	

CONCLUSION

The incident investigation process should be organized in such a way that it enables the rapid identification of the root causes of incident occurrences, i.e., harmful events. The investigation of incidents and the implementation of corrective actions are aimed at improving safety and preventing the recurrence of events that may have adverse consequences for the system, employees, and the environment.

Furthermore, it is necessary to select an appropriate incident investigation modality that is best suited to the business system/organization implementing it, both from the perspective of operational and procedural requirements and in terms of its effectiveness in preventing or mitigating adverse consequences.

The research findings confirmed that incident situations generate consequences both for the business system/organization as a whole and for the occupational safety management system, thereby confirming the initial research hypothesis. Furthermore, the selection of specific modalities, procedures, and approaches used in the investigation of occupational safety incidents influences both the effectiveness of the investigation process and the quality of the outcomes obtained.

In the current era of rapid development in information technologies and artificial intelligence, new opportunities are emerging for their application in the field of occupational safety, particularly in the investigation of safety-related incident situations. The research results indicate that the accurate identification of the causes of incident occurrence is a key factor in the proper development of appropriate and effective protective measures within the occupational safety management system.

The application of these technologies provides opportunities for the introduction of electronic record-keeping procedures, the processing and analysis of large volumes of data, the reduction of investigator subjectivity, and the precise identification of the most significant causes of incident situations based on available data. Ultimately, these capabilities contribute to the establishment and continuous improvement of sustainable occupational safety management systems.

DECLARATIONS OF INTEREST STATEMENT

The authors affirm that there are no conflicts of interest to declare in relation to the research presented in this paper.

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