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OVERVIEW OF METHODS FOR INVESTIGATING ACCIDENTS AT WORK BASED ON AN ACCIDENT IN A MANUFACTURING COMPANY

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Abstract: The aim of this article is to provide an overview of the most commonly used methods for investigating occupational accidents and to demonstrate their practical application, using an example of an accident that occurred in a production company. The article describes the theoretical foundations of event analysis and discusses methods such as the 5 Whys method, the Ishikawa diagram, Technical-Organizational-Human (TOL), FMEA, ETA, and FTA. The analyzed accident case allowed for the identification of technical, organizational, and human factors leading to the event. The article concludes with conclusions and recommendations for preventive measures that can reduce the number of similar incidents in the future.
Keywords: accident**,** safety

1. INTRODUCTION

"An accident is the result of errors made due to lack of knowledge and experience, specific personality traits, poor physical condition, or the stressful nature of the environment or tasks" (Rasmusen, 1982). Investigating occupational accidents is a key element of safety management in enterprises, especially manufacturing companies, where machinery, equipment, and various technological processes are used daily. Every accident carries not only health consequences for the injured party but also financial losses, production downtime, and reputational risk for the company. Therefore, proper analysis of incidents allows not only to identify their causes but also to formulate effective preventive measures. The importance of investigating occupational accidents stems from the need to ensure employee safety and maintain the continuity of production processes. Every accident provides information about improper actions, technical failures, or organizational errors. Proper classification of these events, reliable diagnosis, and appropriate corrective and preventive measures provide an opportunity to limit the negative impact of work processes on the health and even lives of employees and allow for the creation of systemic improvements that reduce the risk of similar incidents recurring.

2. BASICS OF ACCIDENT INVESTIGATION

An accident at work is defined as a sudden event caused by an external factor, resulting in injury or death to an employee, and related to work performance. This definition clarifies the employer's obligations and indicates the need for a detailed post-accident investigation. Accident hazards occurring in the work environment can be divided into: natural, technical, and personal, and based on severity: minor, serious, and fatal, as well as so-called "near misses," which did not result in injury but could have posed a threat. Each category requires a slightly different analytical approach. The indirect cause of accidents is a faulty safety management system, which leads to poor task organization, creating unsafe working conditions and contributing to unsafe behavior. An injury or dangerous event occurs when these factors are met (Lewandowski & Górska, 2010), (Lubrańska, 2024), (Romanowska-Słomka, 2014). Figure 1 shows the phases of development of accident situations.

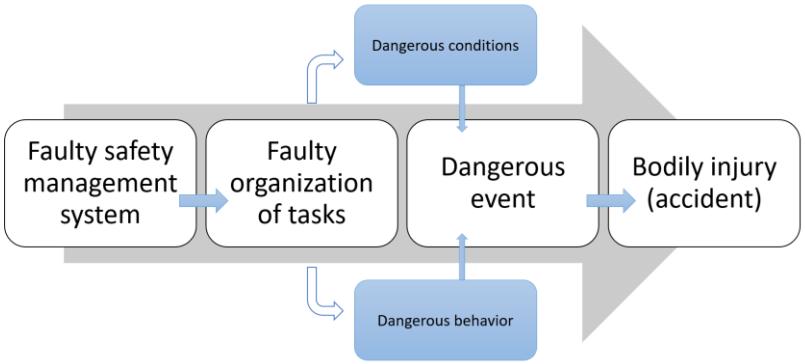

Fig. 1. Phases of accident development

Determining the causes of accidents is crucial for prevention. Accident analysis should be conducted broadly, taking into account both direct and indirect causes. Information on the causes must be included in post-accident documentation (protocols and company accident registers). However, these records often only identify the direct cause of the event, omitting indirect causes. Proper accident analysis allows for their effective elimination, therefore it is important to identify indirect causes such as: inadequate safety policy, acceptance of excessive risk, and the work environment (equipment, materials, technologies, human behavior, improper task organization, inadequate supervision, or negligence) (Krzyśków, et. al., 2015), (Grądziel, 2006). The causes of accidents are shown in Figure 2.)

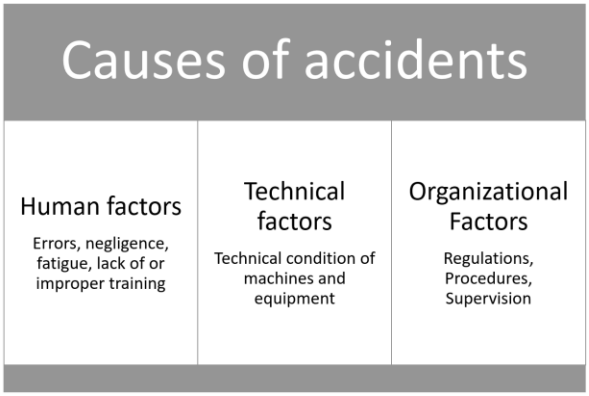

Fig. 2. Causes of accidents

A safety culture is undoubtedly a key factor influencing the number of accidents in organizations. It fosters conscious employee behavior and better enforcement of procedures. Organizations with a strong culture eliminate hazards before they lead to accidents. This means that everyone – from management to new employees – feels responsible for safety and actively promotes it. This leads to fewer accidents and injuries, improved employee well-being, higher productivity and quality of work, and a strong company reputation. The key elements of a safety culture are shown in Figure 3.

Fig. 3. Elements of safety culture

3. ACCIDENT EVENT MODELS. METHODS FOR INVESTIGATING ACCIDENTS AT WORK – OVERVIEW AND CHARACTERISTICS

Accident event models represent the sequence of events or the interconnectedness of indirect causes of accidents leading to injury or loss of health. Accident models are created to understand how and why accidents occur. They also aid in planning actions and building an effective safety system (Łakomy & Nowacki, 2023), (Gałusza & Langer, 2017). The use of models in accident investigations aims to help the accident investigation team develop an informed picture of the accident phases, ask the right questions, and determine the information that needs to be collected. The team then evaluates the collected data, determines directions for further research, and identifies and establishes appropriate preventive measures. The model should meet the following characteristics: enabling a description of the accident event; identifying the direct and indirect causes of the accident; defining the interrelationships between causes; enabling the establishment of preventive measures appropriate to the given event; appropriately positioning these measures in all phases of the accident; linking them to occupational hazards; providing data needed to complete the statistical accident card; and easily adapting to the future European statistics system (Pietrzak, 2003, 2004, 2007, 2014). An overview of methods for investigating accidents at work is presented in Table 1.

Table 1. An overview of methods for investigating accidents

Method	Description
Method of 5 Why	It consists of asking the question "why?" one by one until the root cause is discovered. It is simple, fast and effective, especially in the analysis of individual events.
Ishikawa Diagram	Also known as "herringbone". It allows you to group causes into categories: human, machine, method, material, environment and management. Promotes teamwork.
JSA (Job Safety Analysis)	A method for identifying hazards and assessing risks at different stages of the work performed. In the context of accidents, it allows you to check at which stage of the task irregularities appeared.
FMEA	It analyzes possible errors in systems, evaluating them in terms of impact, probability and detectability. Although used mainly preventively, it can also support post-accident analysis.
TOL	A method that identifies causes in three areas: technical (T), organizational (O) and human (L). It allows you to see how different factors interact. Method indicated for the investigation of minor accidents and for the initial identification of causes in more complex accidents.
Event Tree Analysis (ETA) i Fault Tree Analysis (FTA)	FTA (Error Tree) analysis the causes leading to an event, while ETA (Event Tree) analysis the possible consequences of a single initiating event. These are more complex methods, often used in high-risk industries.
STEP Analysis	Strategic analysis of the company based on four elements: social, technological, economic and political. It is a complex method and consists in recreating a sequence of events and creating a picture of the connections between them.
Analysis by model OARU (Occupational Acident Reserach Unit)	It is based on a process model and shows how the production system moves from the normal phase to the phase in which an accident occurs and is designed to determine and analyze the individual phases of the accident as well as identify many facts that led to the event.
MORT Method (Management Oversight and Risk Tree)	The method is based on a logical scheme of management negligence and excessive risk and penetrates the area of business management.
WAIT Method	A method using deviation analysis. It deals with the search for factors influencing the identified facts, creating links with the results of occupational risk assessment and searching for causes in the field of occupational health and safety management.
SCAT Method (Systematic Cause Analysis Technique)	Analysis of Near-Misses. Systematizes the analysis of accidents at work, taking into account all possible causes.

Source: Romanowska-Słomka, 2014

4. STAGES OF ACCIDENT INVESTIGATION

The process of investigating an accident is aimed at determining the circumstances and causes of the incident**,** and then taking preventive measures. The following stages are standardly distinguished (Table 2):

Table 2. Stages of accident investigation

Lp.	Stage	Description
1.	Reporting and securing the accident site	- notify superiors and health and safety services as soon as possible, - providing first aid to the injured person,

		- securing the place so that there are no further threats, - preservation of evidence and workplace layout.
2.	Appointment of the post-accident team	It consists of: an OHS representative and an employee's supervisor. The team begins formal arrangements.
3.	Collect information about an incident	- visual inspection of the accident site – photos, sketches, measurements, - interviews with the victim and witnesses, - review of documents and procedures (e.g. training, instructions, authorizations), - identification of violations and irregularities.
4.	Analysis of the circumstances and causes of the accident	The course of events is reproduced step by step. The following causes are determined: direct (e.g. lack of machine cover), indirect (e.g. improper supervision), organizational/systemic (e.g. lack of safety culture), Analytical models (Reason, 5xWhy, domino model, etc.) can be used.
5.	Elaborating conclusions and preventive actions	It indicates what needs to be changed to prevent similar accidents: training, procedures, technical changes, protective measures, supervision, etc. Recommendations must be specific and implementable.
6.	Preparation of post-accident documentation	The most important document is the accident report (or accident card). The documentation includes: a description of the event, causes, evidence collected during the proceedings, preventive conclusions. The document is sent to the injured party and the employer.
7.	Monitoring corrective actions	The team supervises whether the recommendations have been implemented, the effectiveness of the measures taken is assessed.

Source: Pietrzak, 2003

Individual steps in the next stages are shown in Figure 4.

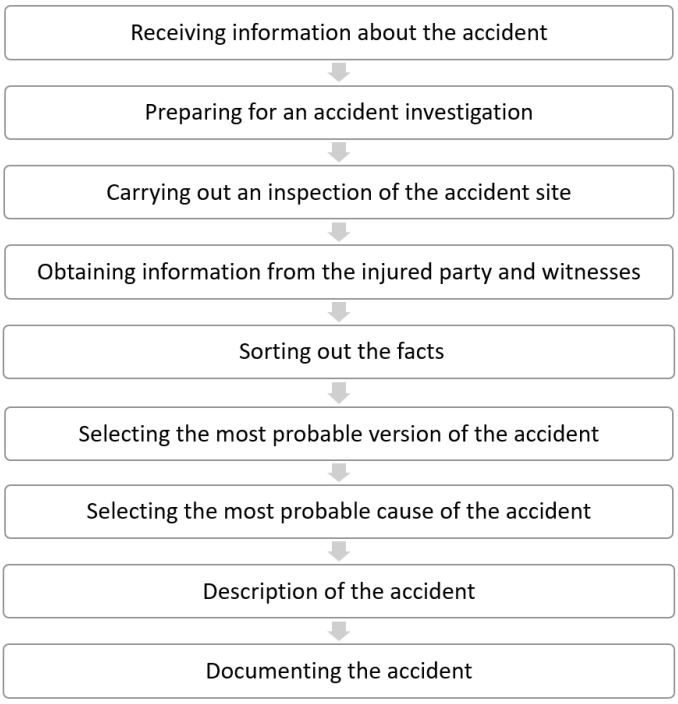

Fig. 4. Stages of accident investigation

5. METHODOLOGY OF RESEARCH - CASE CHARACTERISTICS – DESCRIPTION OF AN ACCIDENT IN A PRODUCTION COMPANY

To demonstrate the effectiveness of each method, an actual incident that occurred at a production plant in the Silesian region was used. The issue of accidents in companies in other industries has also been studied by other authors in their papers (Harabas, & Klimecka-Tatar, 2017), (Klimecka-Tatar & Niciejewska, 2016), (Konopka, 2021) (Tabor, 2022), (Ulewicz, 2018). The analyzed accident case allowed for the identification of technical, organizational, and human factors leading to the incident. Table 3 summarizes basic data regarding the workplace accident.

Table 3. Data regarding the workplace accident

Organizational background	An automotive manufacturing facility specializing in metal processing. It employs several hundred workers working in a three-shift system.
Job description	The employee was operating a hydraulic press designed for forming components. The station was equipped with two-handed controls. Unfortunately, some safety features were temporarily disabled due to maintenance.
Course of the incident	During a forming operation, an operator reached into the press to correct the position of a part. Due to a control system error, the machine made a work movement, injuring the worker's finger.
Consequences	The employee suffered a serious injury to his left index finger and required hospitalization. The company incurred costs for downtime, compensation, and corrective actions.

Source: Based on company data

6. APPLICATION OF SELECTED TEST METHODS TO A SELECTED CASE

Three popular methods were used to investigate the accident: 5Why, Ishikawa's Diagram and TOL method (Majer, 2013).

Method 5 Why

The 5 Why method determined that the immediate cause of the accident was reaching into the press's work area, and the primary cause was a malfunctioning safety system and a lack of clear signage indicating that the safety devices were disabled. The problem lies not with the employee's error, but with the work organization. The primary root cause was a lack of proper supervision and a culture of safety. Figure 5 presents the subsequent questions and explanations in the 5 Why method.

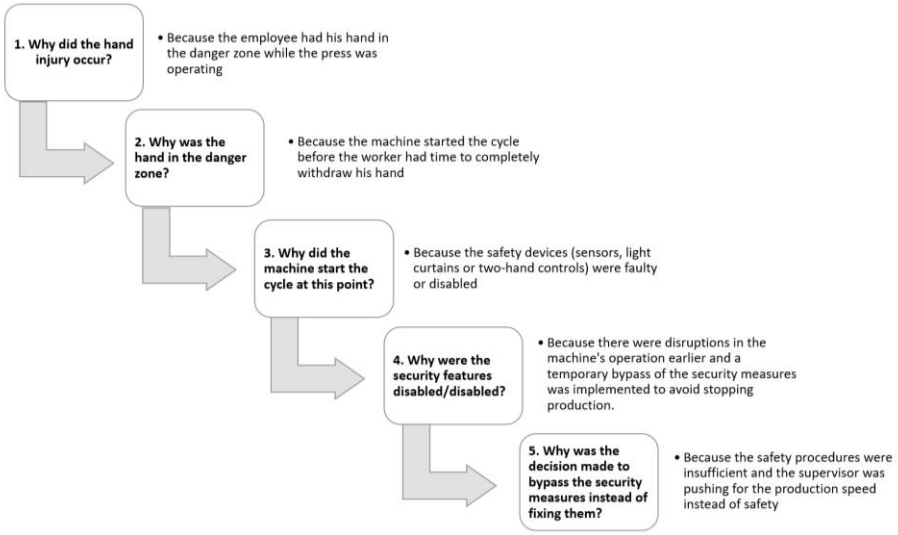

Fig. 5. Questions and explanations in the 5 Why method

The method shows possible preventive actions: an unconditional ban on disabling technical protections; regular service and audits of hydraulic presses; two-hand control or functional light curtains; training for employees and foremen; incorporating safety into the evaluation of production performance.

Ishikawa diagram

Analyzing the accidental event of an employee's hand injury in the discussed enterprise using the Ishikawa diagram (causes and effects), the causes have been divided into classic 6 categories: Human, Machine, Methods, Material, Environment, Management. The analysis indicated the following causes in subsequent categories for the event (Table 4).

Table 4. Causes for the incident

Human	1. lack of awareness of the risks associated with putting your hands in the press work area, 2. routine and haste → inaccuracy of actions, 3. insufficient on-the-job training or occupational health and safety, 4. operator fatigue (shift work, monotony), 5. no license to operate the machine (if applicable).
Machine	1. disabled or malfunctioning technical protections (e.g. light curtains, two-hand control), 2. no sensors preventing starting with the presence of the hand in the danger zone, 3. lack of regular technical inspections, 4. poor technical condition of the press (defects).
Methods/Procedures	1. no machine locking procedure during jam clearing (LOTO), 2. no instructions or instructions that are not very legible, 3. tolerating unsafe work practices, 4. no requirement to report defects and stop production immediately.
Material/Auxiliary Tools	1. improper tools for positioning elements → the need to use your hands, 2. sharp edges of manufactured elements (difficulty in grip), 3. elements difficult to position stably without the involvement of hands.
Working environment	1. poor lighting of the work area, 2. noise that hinders communication in the team, 3. limited space at the stand, 4. messy or slippery surfaces that increase the risk of high-speed work.
Management / Organization	1. management's focus on efficiency instead of safety, 2. disregard for reports of security vulnerabilities, 3. lack of control of compliance with health and safety rules, 4. Insufficient safety culture in the company, 5. evaluation of employees mainly for the pace of work.

Source: Own study based on company data

The analysis shows that the problem is systemic, not just human. The following corrective actions are proposed:

1. immediate commissioning and control of all press protections,
2. implementation of the LOTO procedure when removing jams,
3. prohibition of circumventing security measures under the threat of sanctions,
4. regular training and exams in machine operation,
5. Improved lighting and ergonomics,
6. safety indicators in the assessment of superiors.

TOL

Another method used for the same incident was TOL method (Troubleshooting: Technical, Organizational, and Human). The analysis indicated: disabled safeguards, no LOTO, production pressure, weak procedures, and a lack of supporting tools. The use of TOL analysis is presented in Table 5.

Table 5. Event factors according to TOL method

	Identified deficiencies/risks	**Suggestions for technical actions**	**The most important factor**
Technical (Engineering)	Faulty or physically bypassing protections (light curtains, sensors, covers). No hand detection system in the danger zone. No locks for safe servicing (LOTO). Poor technical condition of the press/lack of regular inspections.	1. Immediate restoration/repair of all protections (curtains, covers, emergency buttons). 2. Installing hand detection/two-handed control or additional physical barriers. 3. Implementation of the LOTO procedure (power blocking/disconnection) and physical interlocks during work at the press. 4. Inspection and maintenance schedule with fault record (e.g. monthly + before any major change).	faulty safety system, steering wheel in service mode
Organizational	Lack of clear procedures for jams and service work. Tolerating production "bypasses" of security. Pressure on performance instead of safety. No system for reporting and immediate closure of reported defects.	1. Update of the job manual — add procedures for dealing with jams, LOTO obligation, emergency steps. 2. Prohibition of working with security bypasses written in the regulations and communicated by management; consequences for violation. 3. Introduction of a stop-the-line reporting process – any employee can stop the line without penalty. 4. Change of managers' KPIs – Taking into account health and safety indicators (e.g. number of requests, audits performed) alongside performance. 5. Workplace security audit - independent post-deployment review (external or internal).	lack of service supervision, outdated instructions

Human (training, behaviour)	Insufficient on-the-job and practical training. Cultural permission for "bypasses", group/production pressure. Lack of regular reminders and workouts with LOTO and emergency procedures.	1. On-the-job training + practical exercises of LOTO and safe operation of the press (catch: exercises on a simulator or practice in controlled conditions). 2. Training for foremen and managers in safety management (how to react, enforce rules, not punish whistleblowers). 3. Communication campaign (posters, briefing) – reminder of the ban on security bypasses and the stop-the-line procedure. 4. Toolbox talks at the machine after each shift – short reminders of risks and actions. 5. Fatigue and ergonomics monitoring – rotations, breaks, workplace improvement.	employee's incorrect assessment of the situation

Source: Own study based on company data

After the analysis, the following implementation plan was proposed:

1. Day 0–3: immediate securing of the site, LOTO for the damaged machine, medical provision of care to the injured person; repair or shutdown of the machine until service (Technical + Organizational).
2. Day 1-7: LOTO procedures, manual update, immediate stop-the-line and LOTO training, security functional test (All).
3. Week 2-4: installation of additional safety features (sensors, two-hand control), implementation of the maintenance schedule (Technical).
4. Month 1–3: implementation of OHS KPIs, post-implementation audit, cyclical training (Organizational + Human).

7. INTERPRETATION OF RESEARCH RESULTS- COMPARISON OF RESULTS AND EVALUATION OF THE EFFECTIVENESS OF THE METHODS

All methods confirmed that the causes were multifactorial. The 5 Why method was quick, but Ishikawa's diagram allowed you to see the broader context. The most useful was a combination of several methods—particularly TOL and Ishikawa—that made it possible to capture both technical and organizational factors.

Table 6. Comparison of the 5 Why, Ishikawa and TOL methods

Method	**The most important conclusion**	**Importance for safety**
5 Why	The direct cause of the accident was the operation of the machine despite the presence of the operator's hands.	Security needs to be restored and tested.
Ishikawa	The accident resulted from many interrelated factors: technical, organizational and human.	Activities must cover the entire system, not just the machine.
TOL	Most errors occurred in the areas of organization and security management.	Processes, training, supervision and risk reporting culture need to be improved.

Source: Own study based on company data

The analysis revealed that the primary cause was the disabling of safety devices without proper procedures or notification of the operator. Organizational deficiencies, such as inadequate supervision of maintenance work, also played a significant role. The accident was the result of a combination of human and organizational errors, not a single act of negligence. The main cause of the injury was the possibility of starting the press with a hand in the danger zone, which indicates insufficient or ineffective technical safeguards. Bypassing the safeguards was tolerated at the plant, indicating a poor safety culture and a lack of supervision and clear procedures for clearing jams and performing service. It also suggests that operator training was insufficient, with a lack of knowledge about the consequences of violating safety regulations.

Recommendations and preventive actions

In summary, the accident was entirely avoidable if the safety system had been properly implemented and enforced. Simply reacting to the incident is not enough—a change in the organization's approach is necessary to prioritize safety over efficiency. Appropriate preventative measures were proposed and implemented for this case. First and foremost, technical changes should be implemented, including modernizing the safety system and automatically blocking the machine from starting in service mode. Organizational improvements were made to establish service procedures and conduct regular machine safety audits. In terms of employee interventions, additional training on LOTO (Lock-and-Target) lockouts has been established to raise awareness of the threats. It is also recommended to promote threat reporting and employee participation in improvement processes, as well as to change the organizational policy: zero tolerance for security breaches.

8. CONCLUSION

A review of accident analysis methods and their practical application demonstrates that a comprehensive understanding of an incident requires a multi-perspective approach. Utilizing multiple complementary methods increases the chances of identifying the root causes and developing effective preventive measures. Analysis using the 5 Whys, Ishikawa, and TOL methods revealed that the accident was not the result of a single employee error, but rather a combination of technical, organizational, and human factors. The accident revealed numerous deficiencies in the safety management system, and improving technical safeguards must be coupled with strengthening the safety culture, supervision, and employee competencies.

Appropriate decisions and proper behaviors of the manager can cause him to influence the degree of motivation and commitment of his subordinates, not only in the interests of the company but also in perceiving the safety of themselves and their co-workers as a priority.

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