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Identification of the Causes of Occupational Accidents Involving Scaffolding Using Lower Silesia as an Example

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Abstract. The article presents the results of research on the causes of accidents at work that involve scaffolding. The basis for the identification and classification of the causes of accidents were post-accident protocols drawn up by labour inspectors. The study involved accidents that occurred in Lower Silesia in the years 2008-2015. Based on the analysis of 41 accidents involving scaffolding, their causes were determined. They were then classified into the following three groups of causes: technical, organizational and human. Analysis of Pareto-Lorenz was applied in order to determine the most common causes in each group.

1. Introduction

6264 accidents happened in 2015 in the Polish construction industry, including 55 fatalities and 74 serious accidents [1]. Severe and fatal accidents in the construction industry are very often the result of a fall from a height. Thus, based on 100 construction accidents that occurred in the United Kingdom, the most frequent event that caused an accident to workers was a fall from a height (24%), followed by being struck by a moving or falling object (22%) [2]. On the other hand, based on an examination of 9358 accidents at work that occurred in the construction industry in the United States, it was found that up to 43.9% of people were injured as a result of falling from height or falling over, and up to 25.7% were injured as a result of being hit by an object in motion [3].

In Polish literature, the problem of working safely at a height and also measures that can be used to protect against falls from height were undertaken by, among others, Dabrowski [4, 5], Kaczyński [6], Baszczyńki and Jachowicz [7] Baszczyński [8] and also Drozd and Kowalik [9]. According to these authors, the largest number of falls from height was caused by an improper stability and strength of a material agent, its hidden defects and also improper use.

The total number of accidents caused by a fall from height in Poland can be found in the studies of the Central Statistical Office called "Accidents at work" [1]. This number includes falls from a structural object that is under construction, falls from scaffolding, falls from a formwork and other similar accident situations. It is not known what is the relation between falls from height and work on constructional scaffolding. The answer to this question is very important because these structures are present on the majority of Polish construction sites.

Systematic controls carried out on building sites by labour inspectors indicated a number of irregularities in the area of ensuring safety on scaffolding. The results of the reports published by the National Labour Inspectorate led the authors of this article to undertake research in this area. The main aim was to define the causes of accidents related to these structures and also to define the most important causes of them.

2. Research methodology

The study was conducted on the basis of data on accidents at work in the construction industry, which was found in the archives of the National Labour Inspectorate (NLI). The direct source of information about the course of accidents were post-accident protocols drawn up by labour inspectors after an accident. It should be noted that according to Polish law, fatal, serious and collective accidents should be notified to the NLI. A post-accident protocol describes the circumstances and details of an accident, actions that were taken by labour inspectors with regards to the notified accident at work, as well as indicating any irregularities, shortcomings and causes of the occurred event.

Accidents at work in the construction industry, which happened in Lower Silesia in the years 2008-2015, were analysed within the framework of the carried-out research. A set of 165 post-accident protocols was received from the District Labour Inspectorates. Their detailed analysis revealed that during the evaluated period there were 41 accidents at workplaces using scaffolding.

Based on the review of subject literature [10-13] and data obtained from the analysis of post-accident protocols, the preliminary conclusions for the creation of the classification of the direct causes of accidents related to work on scaffolding were drawn. For the purpose of the conducted research, the definition of a cause of an accident was assumed according to the regulations of the Central Statistical Office. This definition includes any deficiencies and irregularities related to material agents, the general organization of work and a workplace and also employees and their improper behaviour [1].

One of the most widespread classifications of causes of accidents that are used in the evaluation of accidents at work is the so-called TOH method [14]. It assumes that every accident is a result of three types of causes: technical (T), organizational (O) and human (H). This method has been adopted as a standard for identifying the direct causes of accidents at workplaces with scaffolding. In the above-mentioned groups (T, O, H), a few or several detailed causes were distinguished. The cardinalities of individual causes were defined in each of these groups. In order to identify the most significant causes, analysis of Pareto-Lorenz was applied. The research methodology is presented in Figure 1.

3. Research results and their analysis

Based on the analysis of a set of 41 accidents that involved scaffolding, it was found that 26% of all cases are a result of technical causes, 53% are organizational causes and 21% are human causes. In the particular groups of causes (T, O, H), Pareto-Lorenz analysis was carried out. Its objective was to select the most important detailed causes in each group (T, O, H).

3.1. Technical causes

77 causes of a technical nature were found in the analysed group of accidents. Figure 2 shows a bar graph (i.e. Pareto chart) of the cardinalities of the occurrence of each identified technical cause, which are ordered from maximum to minimum, and also a Lorenz curve that presents the cumulative percentage share of the subsequent causes.

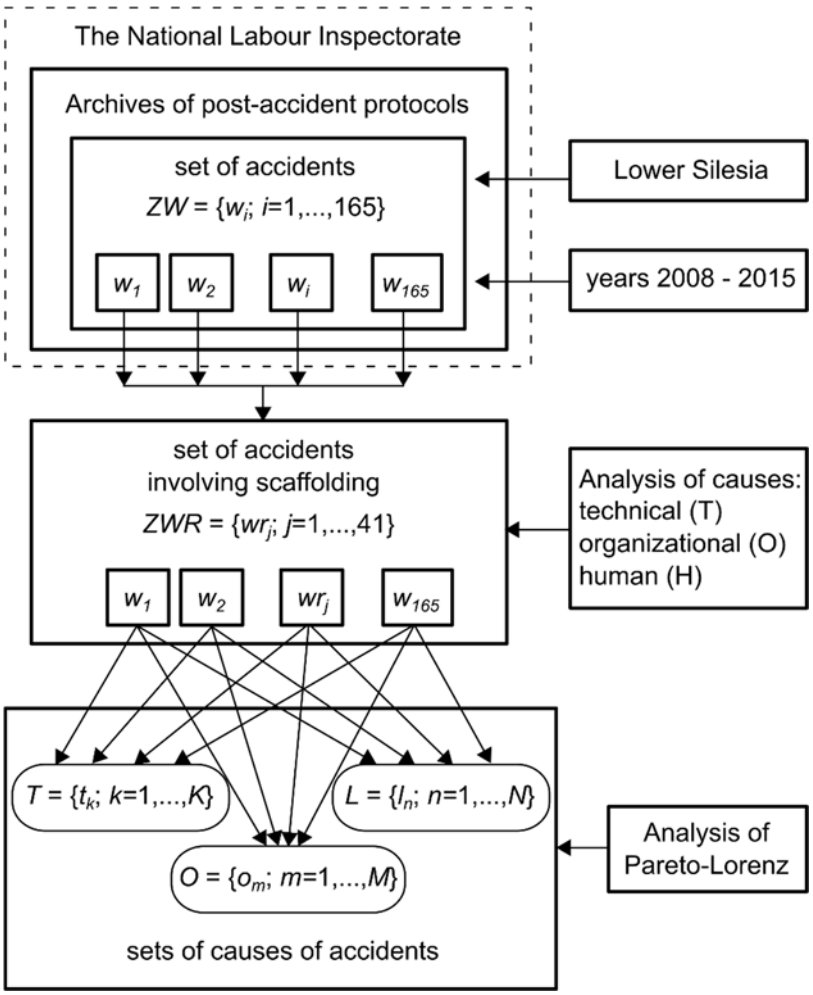

Figure1. Research methodolog

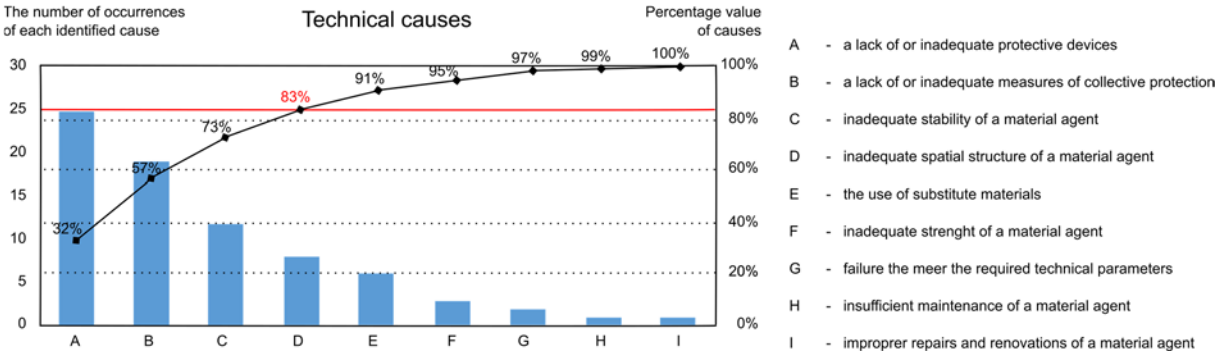

Figure 2. Pareto-Lorenz chart of identified technical causes

- A lack of or inadequate safety equipment and also measures of collective protection. Scaffolding, from which falling from height occurred, was identified with a lack of, among others, external protective top and intermediate railings, curb boards, a working platform with a hatch that enables secure communication between levels, protective barriers that close the ends of the working platforms, devices that help attach personal protective equipment to the construction of the

scaffolding and also internal railings when there is a considerable distance between working platforms and the wall of a building.

- Inadequate stability of a material agent. In the analysed accident set, the following were found: incorrect foundations of scaffolding, the construction of working platforms made of loosely stacked boards, a lack of anchoring of scaffolding to permanent structural elements and also a lack of locking wheels in the case of mobile scaffolding.
- An inadequate spatial structure of a material agent that results from the incorrect assembly of scaffolding. The main irregularities include: a lack of vertical communication divisions that allow safe movement of workers between the levels of working platforms, a lack of full working platforms and also necessary structural elements such as anchors, struts, handrails, platforms and earthing.

3.2. Organizational causes

Figure 3 shows a bar graph (i.e. Pareto chart) of the cardinalities of the occurrence of each identified organizational cause, which are in order from maximum to minimum, and also a Lorenz curve that presents the cumulative percentage share of the subsequent causes.

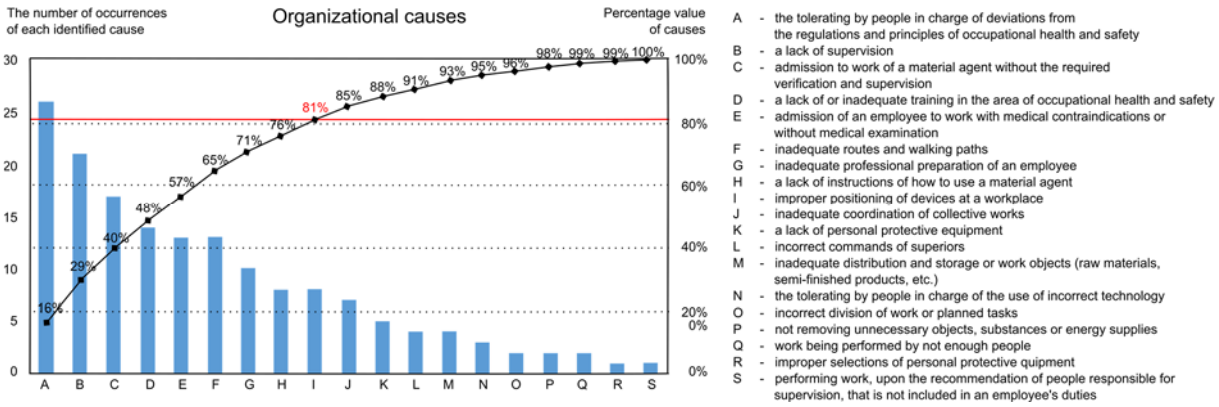

Figure 3. Pareto-Lorenz chart of identified organizational causes

A total of 161 organizational causes were found, of which 81% were the following:

- The tolerating by people in charge of deviations from the rules and principles of occupational health and safety e.g. a lack of occupational risk assessment at workplaces, a lack of employee knowledge about occupational risk assessment, the allowing of work on improperly assembled scaffolding and also the tolerating by management of hazardous working methods.
- A lack of direct supervision of a site or work manager over the carried-out works.
- Admission of scaffolding without the required inspection and maintenance.
- A lack of or inadequate training of employees in the area of occupational health and safety.
- Admission of an employee to work with medical contraindications or without a medical examination.
- Inadequate routes and paths to a workplace that result from an improper placement of scaffolding, which forces an employee to significantly lean beyond the outline of a working platform or forces him to stand on a safety barrier; a lack of vertical communication that enables a secure communication between levels of scaffolding or a lack of a designated danger zone around scaffolding.
- A lack of qualifications of employees to assemble or disassemble scaffolding and also a lack of an assembly / disassembly project of scaffolding.
- A lack of safety instructions for work on scaffolding or employees disregarding such instructions.

- Improper positioning of devices in a workplace, location of a workplace that is less than 3 m from active power lines, setting devices (aggregates, machines) too close to the construction of scaffolding or resting equipment on scaffolding.

3.3. Human causes

Figure 4 shows a bar graph (i.e. Pareto chart) of the cardinalities of the occurrence of each identified human cause, which are in order from maximum to minimum, and also a Lorenz curve that presents the cumulative percentage share of the subsequent causes.

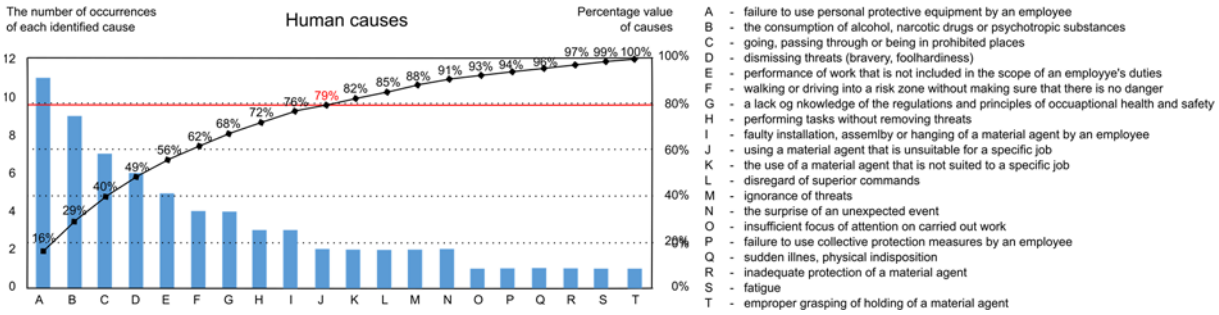

Figure 4. Pareto-Lorenz chart of identified human causes

A total of 68 human causes were found, of which 79% were the following:

- Employees not using personal protective equipment e.g. working in own shoes, which are not adapted to the conditions at a construction site; not using a security line that protects against falling or unauthorized unfastening from fixed elements.
- The psychophysical state of an employee that does not ensure safe work, which is caused by using alcohol, narcotics or psychotropic substances.
- Walking, driving or being in prohibited places e.g. in a danger zone, in an unsecured part of scaffolding, in an area of active high voltage power lines, on top of protective scaffolding barriers and also the failure to maintain an appropriate distance between work posts on scaffolding in both vertical and horizontal directions.
- Employees dismissing hazards that arise from the use of scaffolding that is not completely assembled or the movement of an employee on the outer edge of scaffolding.
- Unauthorised assembly, movement or use of scaffolding.
- Improper employee behaviour, which is caused by a lack of knowledge regarding the regulations and principles of occupational health and safety and also a lack of knowledge about occupational risk and the hazards associated with performed work.
- Performing actions without removing threats and thus working in a danger zone with an active device or active high-voltage lines.

4. Conclusions

Analysis of accidents involving falls from scaffolding, which took place in Lower Silesia in the years 2008-2015, enabled the following conclusions to be drawn:

1. Causes of accidents included causes of a technical (T), organizational (O) and human (H) nature. 26% of all the causes were technical causes, 53% were organizational causes and 21% were human causes.

2. Analysis of causes, which was carried out using the Pareto-Lorenz method, indicated the causes which have had the greatest influence on the occurrence of accidents.
3. There were 77 technical causes found in the analysed set of accidents. The biggest influence on the formation of accidents came from a lack of or inadequate equipment that secures work posts on scaffolding, and also improper collective protection measures e.g. roofing or protective nets, poor stability of scaffolding or its components and also an inadequate spatial structure of scaffolding.
4. There were 161 organizational causes found. In this set, the most common were the following causes: the tolerating by people in charge of deviations from the regulations and principles of occupational health and safety, a lack of direct supervision of a site or work manager during the performance of work, using scaffolding without it being accepted to be used, a lack of or inadequate training of employees in the area of occupational health and safety, admission of an employee to work with medical contraindications or without medical examination, inappropriate routes and paths to workplaces at a construction site, inadequate professional preparation of an employee regarding the assembling or disassembling of scaffolding, a lack of instructions for safe work on scaffolding or not introducing employees to such instructions and also the improper positioning of devices at a workplace.

There were 68 human causes found. 79% of them were as follows: failure to use personal protective equipment by an employee; an improper psychophysical state of an employee caused by alcohol, drugs or psychotropic substances; walking, driving or being in prohibited places; daring and risky behaviour of an employee due to them disregarding threats; execution of work that is not included in the employee's responsibilities; an employee's incorrect behaviour due to ignorance of the regulations and principles of occupational health and safety and also performing tasks without removing a threat e.g. when a device is not switched off or when working near high-voltage lines.

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