

Analysis of the causes and consequences of falls from scaffolding using the Polish construction industry as an example

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Abstract. The results of research published in many publications indicate that the scale of the problem of accidents at work in the construction industry is significant. Fatal and serious accidents, which in the construction industry are often a result of a fall from a height and associated with working on scaffolding, have a particularly strong impact on society. Systematic controls carried out on Polish construction sites indicate irregularities in the area of ensuring safety on scaffolding. As a result of conducted own studies, dozens of accidents caused by falls from scaffolding were selected from the total number of accidents at work in the construction industry and then analysed. The aim of the research was to identify the causes of these accidents and their consequences. The results of studies conducted in this area will be the content of the article.

1. Introduction

Numerous national and international publications highlight the high accident rate in the construction industry [1,2,3,4,5]. 6264 accidents happened in 2015 in the Polish construction industry, including 55 fatalities and 74 serious accidents [6]. 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%) [7]. 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 a height or falling over, and up to 25.7 % were injured as a result of being hit by an object in motion [8].

In Polish literature, the problem of working safely at a height and also measures that can be used to protect against falls from a height were undertaken by, among others, Dabrowski [9, 10], Kaczyński [11], Baszczyński and Jachowicz [12], Baszczyński [13] and also Drozd and Kowalik [14]. According to these authors, the largest number of falls from a height was caused by an improper stability and strength of a material agent, its hidden defects and also improper use.



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 work on scaffolding and also to define the most important causes of them. The research also involved the evaluation of the consequences that falls from scaffolding have on injured people.

2. Research methodology

In order to identify the most common causes and effects of accidents connected to scaffolding, documents included in the archives of the National Labour Inspectorate (NLI) were examined. The direct source of information about the course of accidents were post-accident protocols drawn up by labour inspectors after an accident. Within the framework of the conducted research, all accidents that took place in the years 2008-2015 in the construction industry in the following voivodships (provinces) were analysed: Lower Silesia, Lodz, Mazovia, Malopolska and Wielkopolska. A set of about 700 post-accident protocols was received from the District Labour Inspectorates. Their detailed analysis revealed that during the evaluated period there were 177 accidents at workplaces using scaffolding.

Each accident at work is caused by at least several causes and results in injuries to the body of a victim. 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 [6]. Action of a mechanical, thermal or electric agent on a human's body can cause injury, and thus formation of damage within cells, tissues and organs.

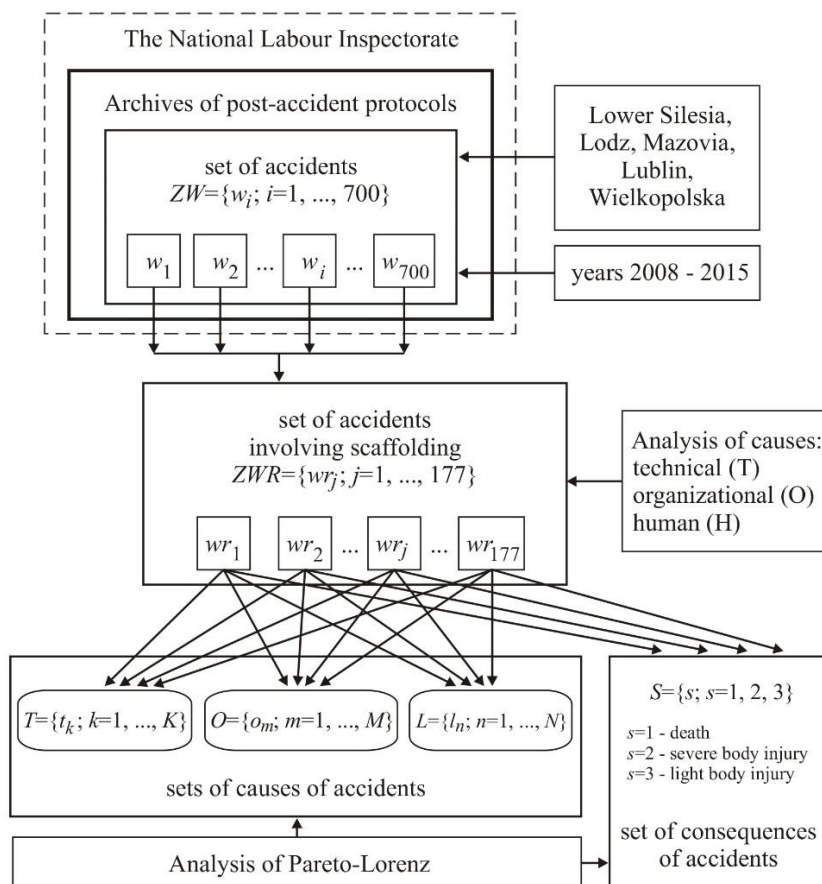


Figure 1. Research methodology [own work].

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 [15]. 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. Individual accidents were also analysed in terms of the effects they had on an injured person. The research methodology is presented in Figure 1.

3. Research results and their analysis

Based on the analysis of a set of 177 accidents that involved scaffolding, it was found that 24,6%, of all cases are a result of technical causes, 48%, are organizational causes and 27,4% 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). It was assumed that significant causes are the ones that were found in approximately 80% of accidents involving scaffolding.

3.1. Technical causes

278 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.

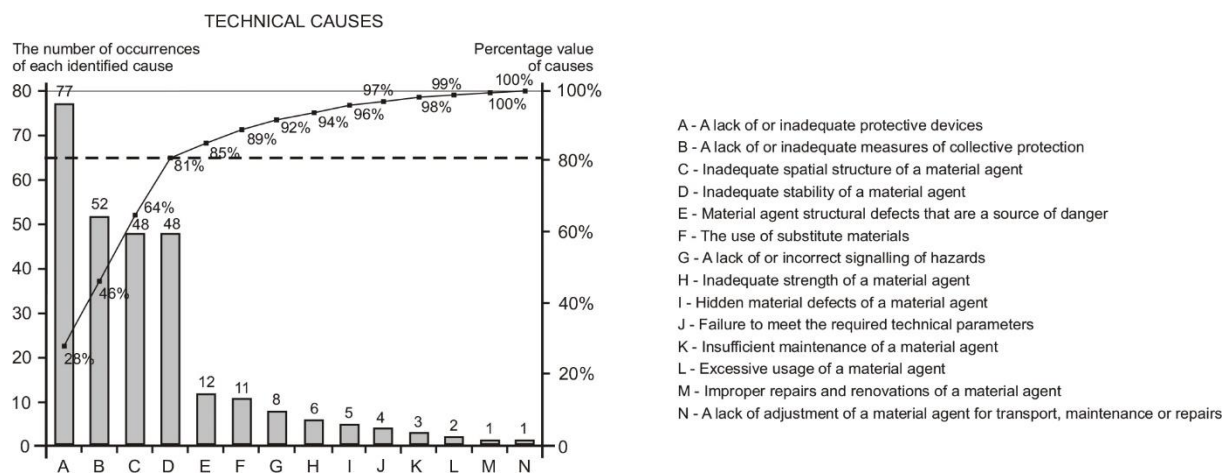


Figure 2. Pareto-Lorenz chart of identified technical causes [own work].

From the above chart, it can be concluded that in the set of identified technical causes, 81% are the following:

- A. B. A lack of or inadequate safety equipment and also measures of collective protection. Scaffolding, from which falling from a 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.
- C. 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.

- D. 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.

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.

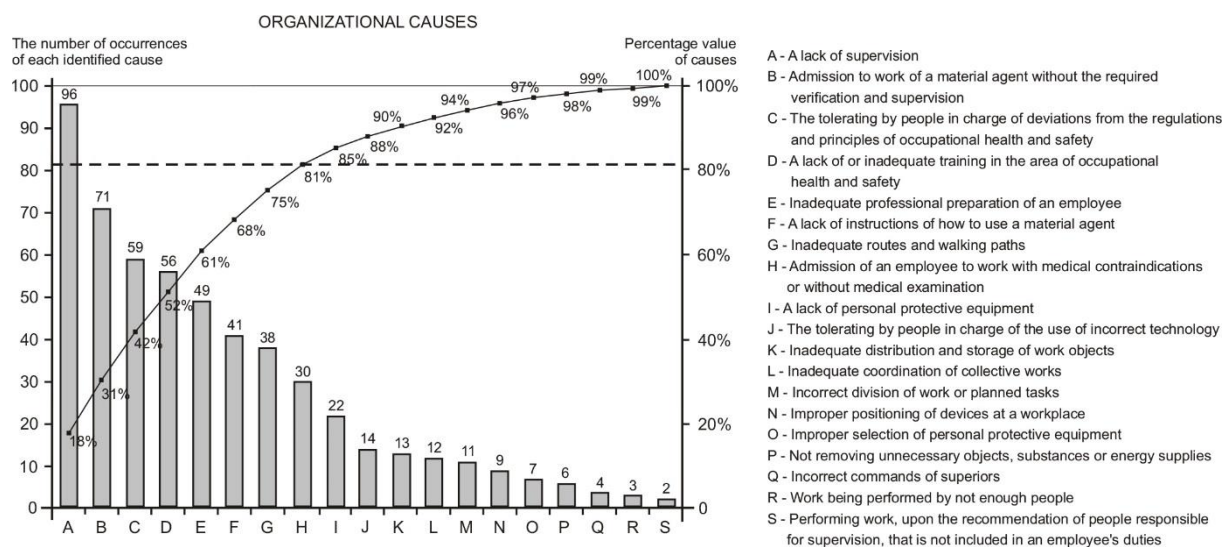


Figure 3. Pareto-Lorenz chart of identified organizational causes [own work].

A total of 543 organizational causes were found, of which 81% were the following:

- A. A lack of direct supervision of a site or work manager over the carried out works.
- B. Admission of scaffolding without the required inspection and maintenance.
- C. 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.
- D. A lack of or inadequate training of employees in the area of occupational health and safety.
- E. A lack of qualifications of employees to assemble or disassemble scaffolding and also a lack of an assembly / disassembly project of scaffolding.
- F. A lack of safety instructions for work on scaffolding or employees disregarding such instructions.
- G. 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.
- H. Admission of an employee to work with medical contraindications or without a medical examination.

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.

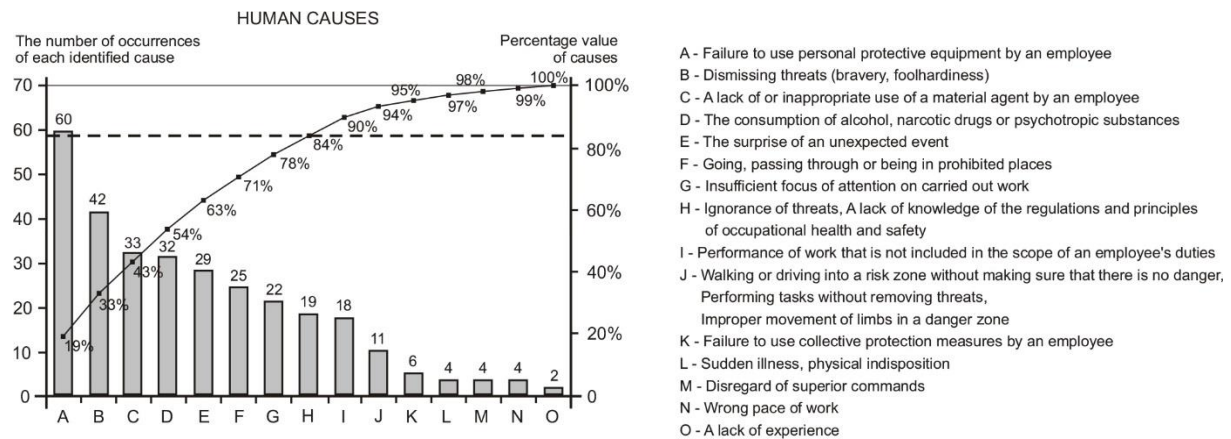


Figure 4. Pareto-Lorenz chart of identified human causes [own work].

A total of 311 human causes were found, of which 84% were the following:

- A. 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.
- B. 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.
- C. Performing work on incomplete and improperly assembled scaffolding.
- D. The psychophysical state of an employee that does not ensure safe work, which is caused by using alcohol, narcotics or psychotropic substances.
- E. Being surprised with an unexpected event, a lack of quick reaction to an event.
- F. 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.
- G. A lack of appropriate concentration on performed work.
- H. 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.

4. The effects of falls from scaffolding

Accidents are divided into fatal, severe and light with regards to the effects they have on the body of a victim. A fatal accident at work is one that results in death within a period of time that does not exceed 6 months from the date of the accident [6]. A severe accident at work is considered as an accident that results in severe body injuries such as loss of sight, hearing, speech or reproduction ability; other body injuries; incurable diseases; life-threatening illnesses; permanent mental illnesses; total or partial incapacity to work; permanent or significant disfigurement or distortion of the body and also health impairment that affects the basic functions of the body [6]. Accidents that are not classified as fatal and severe are considered as light.

A set of 177 occupational accidents involving scaffolding contained 20.9% of fatal accidents, 43.5% of accidents resulting in severe body injuries and 35.6% of accidents classified as light (Fig.5).

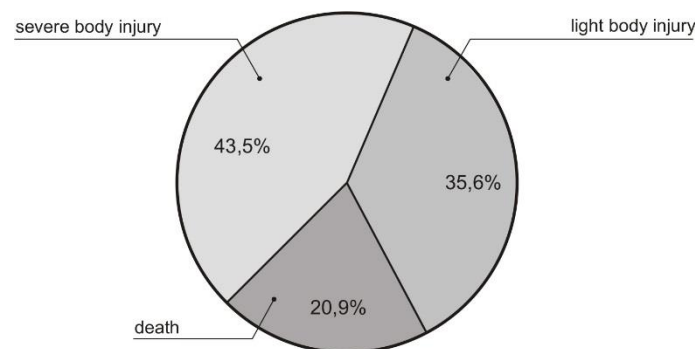


Figure 5. Percentage share of the types of accidents in relation to their total number [own work].

Falls from a height result in numerous injuries located in different parts of the body. Figure 6 shows a graph of the cardinality of the occurrence of selected types of injuries caused by falls from a height.

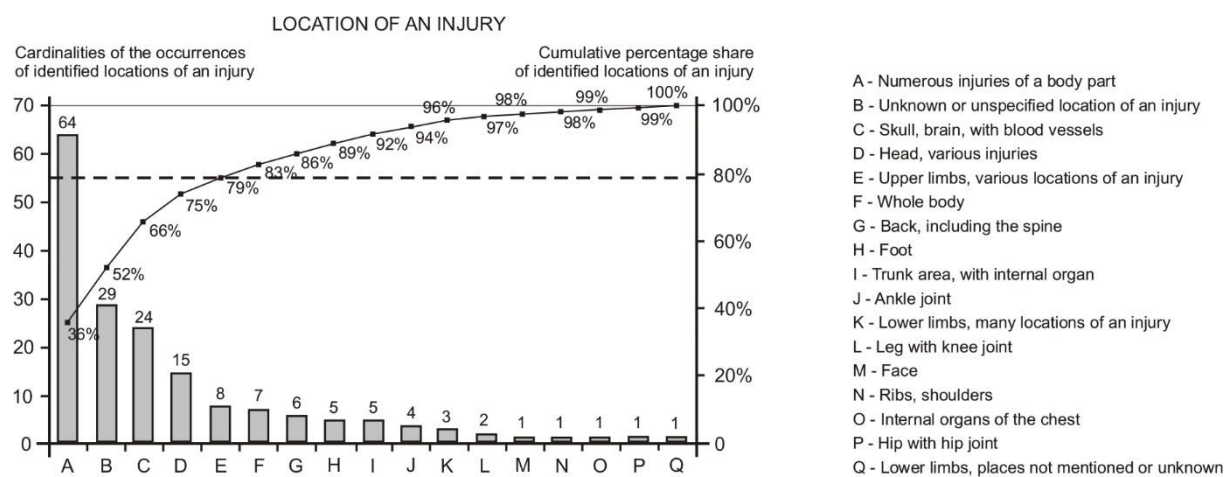


Figure 6. Location of injuries caused by falls from scaffolding [own work].

In 36% of the assessed accidents, injuries were located in several areas of the body, 16% of accidents had no specified area of injury, 14% resulted in skull and brain injuries and 9% resulted in various head injuries. These injuries accounted for 79% of all the reported injuries.

5. Conclusions

Analysis of accidents involving falls from scaffolding, which took place in Poland in five different voivodships (provinces) 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. 24,6% of all the causes were technical causes, 48% were organizational causes and 27,4% 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 278 technical causes found in the analyzed 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 534 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.

5. There were 311 human causes found. 84% 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 behavior of an employee due to them disregarding threats; execution of work that is not included in the employee's responsibilities; an employee's incorrect behavior 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.
6. 20,9% of fatal accidents, 43,5% of accidents resulting in severe injuries and 35,6% of accidents classified as light were found in the set of analysed accidents involving scaffolding.
7. Analysis of the effects of falls from a height, which was carried out with the use of the Pareto-Lorenz method, showed the injuries that most commonly arise as a result of falling from scaffolding. These injuries involve numerous and serious simultaneous damage to different parts of the body, damage to the head and also to upper limbs.
8. Numerous causes of occupational accidents are results of ignorance and breach of rules on safety and health at work. Among such causes there are: lack of supervision, employing the worker with medical contraindications or without medical examinations, absent or deficient training on safety and health at work. Elimination of the causes of accidents related to non-compliance with labour law will certainly enhance work safety in construction.
9. The results of the analysis confirm the results obtained by the researchers from other countries. It can be said, on the basis of foreign papers analysis and own research, that breach of regulations and ignorance of construction safety rules are the most common causes of accidents [4,8].

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