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A Computer Knowledge Database of accidents at work in the construction industry

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Abstract. At least 60,000 fatal accidents at work occur on building sites all over the world each year, which means that on average, every 10 minutes an employee dies during the execution of work. In 2015 on Polish building sites, 5,776 accidents at work happened, of which 69 resulted in the death of an employee. Accidents are an enormous social and economic burden for companies, communities and countries. The vast majority of accidents at work can be prevented by appropriate and effective preventive measures. Therefore, the Computer Knowledge Database (CKD) was formulated for this purpose and it enables data and information on accidents at work in the construction industry to be collected and processed in order to obtain necessary knowledge. This gained knowledge will be the basis to form conclusions of a preventive nature

1. Introduction

On the basis of statistical data published by the Central Statistical Office in Poland, there were on average 92,000 occupational accidents in all sectors of the economy in the years 2008 to 2015, in which 370 people were killed in each year. In the construction industry in 2015, 69 construction workers died and the number of accidents amounted to 5,776. The construction industry in Poland is in eighth place in the ranking of individual sections of the economy regarding the severity rate of accidents. The incidence rate of accidents at work amounted to 6.96 in relation to 1,000 workers [1].

The International Labour Organization during the recent XX World Congress on Occupational Health and Safety, which was held in 2014 in Frankfurt, stated that about 350,000 workers die each year as a result of accidents at work [2]. On the basis of available statistical data published by the Central Statistical Office of the European Union regarding 2012, it can be concluded that the building industry is classified in second place in terms of the incidence rate of accidents at work resulting in more than 3 days of absence from work, and in second place in terms of the incidence rate of fatal accidents at work. In all twenty-seven countries of the EU, more than 1,100 accidents at work occur each day [3].

The aim of the research conducted by the authors of the article is to create a knowledge database of occupational accidents in the Polish construction industry [4]. This database will be a repository for collected archival data and will enable a variety of research and analysis of the contained set of information to be conducted. Detailed analysis of the circumstances, causes and courses of events will allow the mechanisms of their formation to be determined and will therefore be the first step in the process of the prevention of accidents and the improvement of safety in the workplace.

2. Archive survey

The main body of the supervision and control of compliance with labour law in Poland, including the rules and principles of occupational health and safety, is the State Labour Inspectorate (SLI) [5]. The tasks of the SLI include, among others, actions that prevent and reduce hazards in the work environment and in particular investigations of the circumstances and causes of accidents at work. Moreover, it monitors the measures that are used to prevent accidents [6]. The Act [5] and Regulation [7] imposes an obligation on the authorities of the State Labour Inspectorate to study fatal, serious and collective accidents as well as catastrophes.

Each SLI control in the area of investigating the circumstances and causes of accidents at work is a separate case documented by a set of post-accident protocols. A post-accident protocol contains a description of the actions carried out in connection with the claimed accident and presents the circumstances and the course of an accident. Moreover, it indicates any irregularities, shortcomings and reasons of the occurred event. Based on this information, the course of a single accident at work can be reconstructed.

The Computer Knowledge Database (CKD) about accidents at work was created within the framework of conducted research regarding the phenomenon of accidents in the construction industry. The proposed structure of the Knowledge Database includes general information about an accident, the data of an injured person and also information about the course of an accident. Describing the accident at work used to codes included in the methodology developed by the European Statistical Office obligatory in investigating the circumstances and causes of accidents at work in the European Union countries [8,9]. In accordance with the rules on collection of data on accidents, each defined term related to circumstances, course and causes of an accident is assigned a numerical code as defined in Annex 2 to Regulation [10], for example:

- when analysing the place of the occurrence of an accident, a place with assigned 3-digit code is identified, e.g. the construction site - a building object under construction, code: 021; a building being demolished, repaired or maintained, code: 022; an opencast quarry, opencast mine, excavation or trench, code: 023, etc.
- when analysing the process of work that is carried out by the injured person at the time of accident initiation, the following processes characteristic for the construction industry, were distinguished: excavation, code: 21; a new construction – building, code: 22; a new construction – civil engineering, infrastructures, roads, bridges, dams, ports, code: 23; remodelling, repairs, extensions, building maintenance – all types of constructions, code: 24; demolition – all types of constructions, code: 25

The contents included in post-accident protocols should always be considered as a genuine description of the course of an accident. It is therefore required that the information that is implemented into the CKD corresponds to the facts that were found by labour inspectors. When analysing documentation, particular attention should be paid to the causes of accidents that are indicated by labour inspectors, and thus the elements that failed during the work process. Things or situations that have worked well, e.g. barriers or training courses, are rarely mentioned.

3. Construction of the Computer Knowledge Database

The Computer Knowledge Database is a system created in the form of a web application that is installed on the Wroclaw University of Science and Technology server. The system was built in multi-layer architecture using the J2EE application and consists of three layers, namely: a presentation layer, a business logic layer, a database layer. The structure of the system is shown in Figure 1. A user has an access to the server via a web browser.

The outer layer is responsible for the interaction of the application with a user, i.e. for displaying and entering data. The main task of the presentation layer is to process the data received from the application (the business logic layer) and present it graphically in a user-friendly language. The business logic layer is responsible for processing requests from the user. In this layer, the application enables information to be entered, searched, exchanged and processed by the user. It is possible to also administrate and secure

the system. Data to be sent from the database to the presentation layer is prepared in this layer. In turn, the database layer stores and provides access to data used by other layers: the business logic layer and the presentation layer. The database supports the following file formats: Word, Excel, PDF.

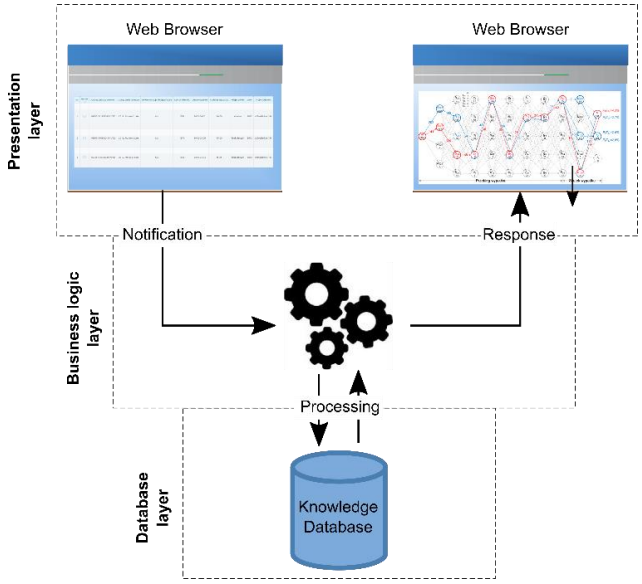

Figure 1. Simplified diagram of the architecture of the Computer Knowledge Database [own work].

A dynamic website of the application has been created on the basis of information stored in the database. The business logic layer receives a notification from the presentation layer. In the next step there is communication with the server of the database (processing), i.e. sending of a notification to the database layer, receiving output data from the database and then processing it. On the basis of the processed data, a HTML code is generated and sent back to the presentation layer with the use of a HTTP protocol.

Figure 2 shows the components implemented into the Computer Knowledge Database, the dependencies between them and their functionality

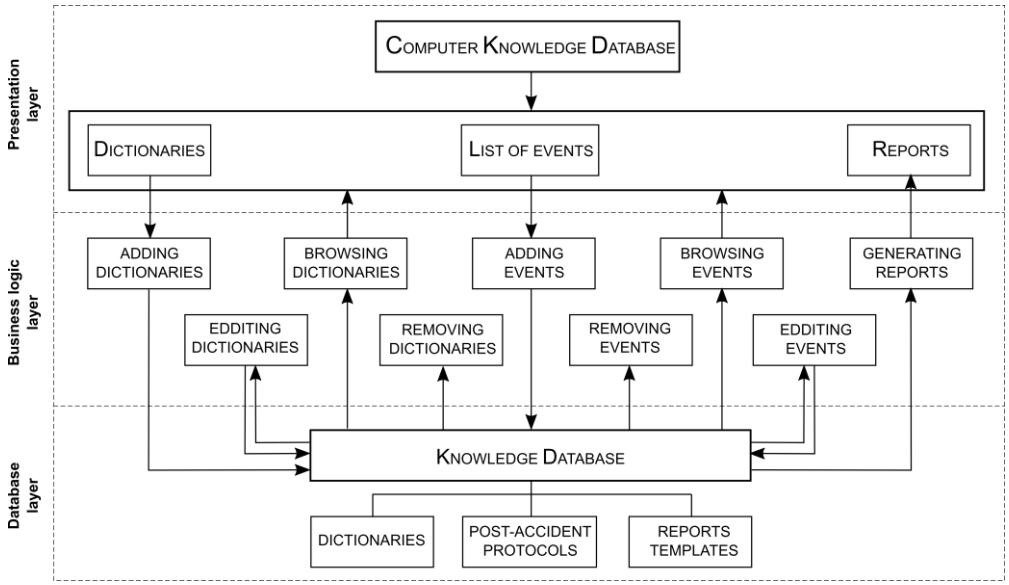

Figure 2. Components of the Computer Knowledge Database and their dependencies [own work].

The application uses Java programming language and technologies such as Spring Framework, Hibernate, JSF, PrimeFaces, PostgreSQL and AJAX, and also the following libraries: wicket, bootstrap, jquery, Springsecurity, Jasperraport, Jackrabbit.

4. Entering data into the Computer Knowledge Database

Based on thorough analysis of post-accidental protocols, it is possible to reconstruct, step by step, the course of an event and then enter information about an accident into the Computer Knowledge Database. The CKD is built in the form of a two-dimensional table. Each row contains information about one accident. The terms defined in dictionaries are located in the subsequent columns. Figure 3 shows part of the user interface in the form of a list of events.

Nr	Wybór	Oznaczenie protokołu	Oznaczenie robocze	Dokumentacja fotograficzna	Rok urodzenia	Data wypadku	Godzina wypadku	Miejscowość	Rok	Województwo
No	Choice	The symbol of a source document	Temporary symbol	Photographic documentation	Year of birth	Date of the accident	Time of the accident	Place of occurance	Year	Regions of Poland
1	☐	16235-5317-K007-Pt/12	2012_Protokol 1_Wr	tak	1992	2012-04-01	14:00	Wrocław	2012	dolnośląskie [16]
2	☐	16240-5303-K019-Pt/12	2012_Protokol 2_Wr	tak	1979	2012-03-09	15:00	brak danych	2012	dolnośląskie [16]
3	☐	16049-5303-K035-Pt/12	2012_Protokol 3_Wr	tak	1956	2012-04-24	15:15	brak danych	2012	dolnośląskie [16]

Figure 3. Fragment of the user's interface in the form of an event list.

In order to more accurately collect data on accidents, apart from a distinctive code, an additional window was formulated to enter a description that allows information about the introduced concept to be more detailed and precise.

Entering data to the CKD is divided into five stages. In the first stage, a user enters general information about an accident at work, i.e. District - post-accident protocol, a temporary symbol, place of occurrence, year, general description, the circumstances of the accident, weather conditions during the work process and also the size of the enterprise where the accident occurred. In addition, in this stage a source document i.e. a digital protocol in pdf or doc format is uploaded to the database. Moreover, it is possible to provide information about the photographic documentation included in a protocol. The view of the window for entering general information about an accident is shown in Figure 4a.

Information about the injured person is introduced in the second stage, i.e. gender, age, citizenship, employment status, occupation, work experience and information about the preparation of an employee to perform work (information about completed trainings: initial general training, on-the-job training and periodic training; a medical certificate stating the absence of contraindications to perform work at the workplace; possession of additional qualification certificates). The view of the window for entering information about a victim is shown in Figure 4b.

In the third and fourth stage, a user enters the following information about an accident and its course into the CKD: the date and time of the accident, the number of hours worked by a victim up until the time of the accident, the working environment, the working process, the specific physical activity by the persons injured at the time of the accident, the material agent of the specific activity performed by the persons injured at the time of the accident, the event that is a deviation from the normal state, the material agent of the event that is a deviation from the normal state, the event that cause an injury, the material agent that is the source of an injury associated with the event that causes the injury, the type of injury,

the location of injury, the type of accident and also the result of the accident. The window views are shown in Figure 5.

In the final fifth stage, the causes that led to an accident at work are entered into the database. The causes are divided into technical, organizational and human [11] (Fig. 6).

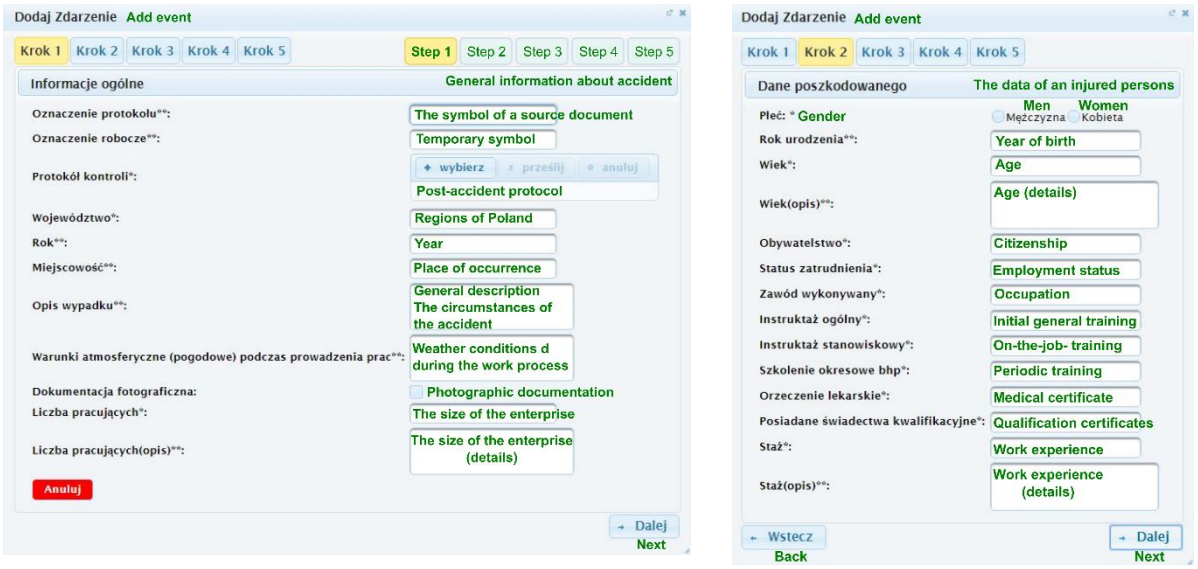

Figure 4. View of the window for entering information

a) general information about an accident. **b)** information about a victim.

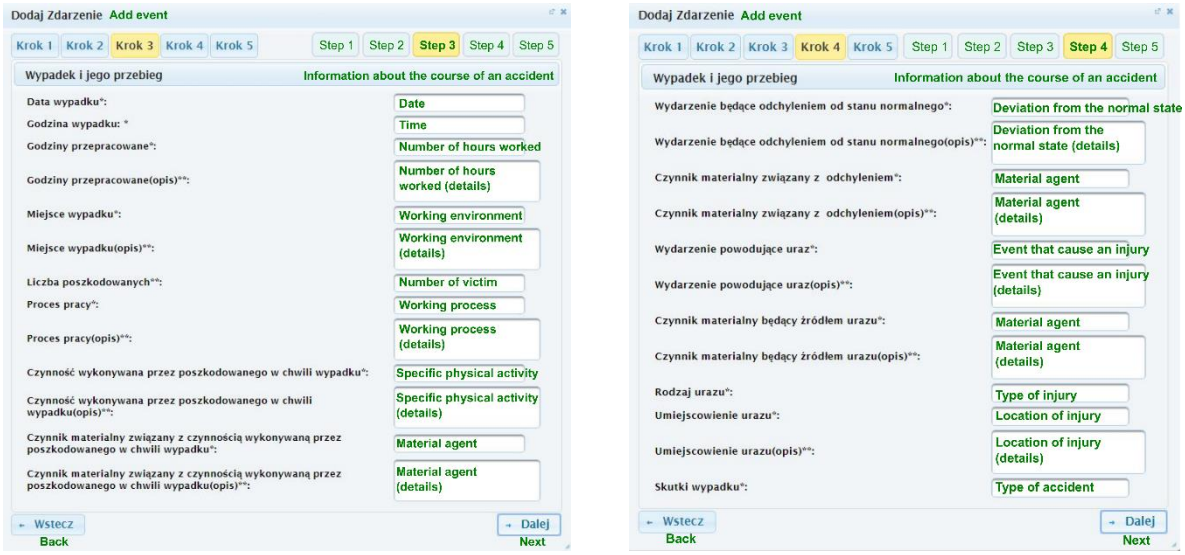

Figure 5. View of the window for entering information about an accident and its course.

5. The implementation of data about an accident into the CKD – a case study

An accident that occurred on 6 June 2011 during the construction of a sanitary sewage system in the village of Karczyce in Lower Silesia was analysed as an example. On the day of the accident, five employees were at the work place: three employed as sanitary installation fitters, one as a digger operator and one as a truck driver. Supervision of the work had to be carried out by a construction manager who was not at the construction site on the day of the accident. The workers arrived at the building site at about 10 am. The construction manager, by telephone, assigned them work associated with the repair of a road.

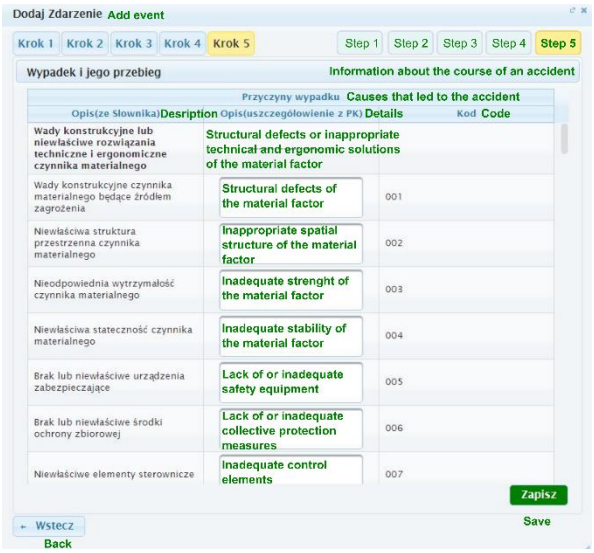

Figure 6. View of the window for entering information about the causes of an accident.

At about 12 o'clock the workers that were present at the building site began to perform the assigned works related to the execution of the sewer system. The digger operator started his work. After completing the excavation to a depth of about 1.2 meters the workers found a signalling tape from the discharge pipe of the sewers. Due to the fact that the pipe was located in the axis of the excavation, it was not possible to insert a casing with a height of 2.7 m and a width of 1.45 m into the prepared trench. The casing would not fit into the excavation because of its dimensions. It was decided to insert a smaller casing with a height of 2 m and a width of 1.1 m. The digger operator was taking soil from the interior of the casing while it was at the same time being pierced deeper and deeper until it reached a depth of about 3.4 m. It should be noted that because the depth of the trench was equal to 3.4 m and the overall height of the casing was equal to 2.0 m, the casing only protected the lower part of the excavation. The slope of the excavation located above the casing, with a height of approximately 1.4 m, was not secured. Some of the excavated material was taken away by truck and the rest was stored next to the edge of the excavation.

After reaching the desired depth, one worker entered the trench in order to find the end of the sewage pipe to which the other workers were meant to attach subsequent sections. The second worker also entered the excavation. The work was supported with the help of the third worker who was standing on the struts of the casing. He was, from the top and with the use of a piece of steel plate, trying to stop the subsidence of sand from the upper part of the trench slope.

At about 4 p.m., during the execution of work, a wedge of soil situated above the casing collapsed and the two workers were buried in the trench. The victims died on the building site.

Table 1 provides some information about an accident at work, which was introduced to the Computer Knowledge Database together with the adopted code designations.

Table 1. Information about an accident at work [fragment].

No	Date of accident	Time of accident	Province		…	Work process			…
			Description	Code		Description	Details	Code	
27	2011-06-06	16:00	Lower Silesia	16	…	Building of infrastructure	Building of a sewer network	23	…

Table 1. Information about an accident at work [continuation].

…	An event being a deviation from the normal state			…	Material agent associated with a deviation from the normal state			…
	Description	Details	Code		Description	Details	Code	
…	Slipping, falling, collapsing of a material agent, fall of a material agent from above	A wedge of soil collapsed during the execution of works	33	…	Elements of the natural environment and atmospheric phenomena	Soil, soil wedge	20.02	…

Figure 7. Photos of the accident site [post-accident protocol].

Introducing the details on the large number of accidents to the Computer Knowledge Database will allow to perform statistical data analyses. Such analyses may relate to quantitative analysis of data contained in the database, establishing the most likely scenario of the accident etc. Depending on the range of statistical analyses, Excel or Statistica are used to perform them. The analyses results are presented in the form of tables and charts.

6. Application of the Computer Knowledge Database

The Computer Knowledge Database is an archive in which code and descriptive information about individual accidents at work in the construction industry are stored in a structured way. The use of codes allows information that is relevant to the conducted analysis regarding occupational safety to be quickly obtained. Analysis of a set of 350 occupational accidents from the construction industry that were included in the database enabled, among others, the following conclusions to be formulated:

- 202 cases of accidents at work, which were assigned to the construction sector, occurred during the construction of new buildings, while 141 cases occurred during the renovation and demolition of existing building objects.
- The process that causes the most accidents and is performed during the initiation of an accident is the construction of new buildings. There were 148 such situations identified. 131 accidents happened during the rebuilding, repair, extension and maintenance of building objects, and 38 during the construction of infrastructure facilities.

- Accidents occurred most commonly during the movement of an employee along a flat area, ascending or descending to another level, entering or leaving other spaces and also during jumping or moving. There were 126 such reported cases. In 89 cases, the handling of objects was the activity that was performed by the victim and in 71 cases the work involved the use of hand tools.
- The largest group of material factors related to accidents in the construction industry, which was identified in 176 cases, consisted of buildings, structures and their components above ground level, including among other things: roofs of buildings, stationary or mobile scaffolding and also work platforms or ladders. Another often identified material factor was heavy transport vehicles, which was seen in 39 cases.
- The most common events that are incompatible with the appropriate course of the work process include slipping, stumbling or the falling of a person, which was recorded in 149 cases, and also the damage, bursting, breaking off, slipping, falling and collapsing of a material factor, which occurred in 118 cases.
- The falling of a victim from a height and from buildings or structures located above ground level occurred in 136 accidents.
- The most common event that caused injury was a collision with an immovable object. Such events were reported in 204 cases, out of which the hitting of a horizontal surface located at ground level occurred in 173 cases.
- 141 analysed cases were followed by the death of a victim. Serious injuries happened in 201 cases, and light injuries in 8 cases.

7. Summary

The construction industry in Poland and other countries in the world is a section of the economy with a very high accident rate. Research and analysis of accidents in the construction industry with regards to their various aspects are essential for carrying out preventive measures. The Computer Knowledge Database was created to gather a large amount of data on accidents at work in the Polish construction industry and is the repository for collected data. The article presents the structure of the CKD in the form of a two-dimensional table. Each row of this table contains information about one accident. Information regarding accidents is recorded in a descriptive form and by its code. The matrix form and code designations that were used in the CKD enable the database to be easily searched through to find information of interest. The CKD allows various statistical analyses of the contained set of accidents to be conducted. The article also describes how to input data about an accident and presents the results of exemplary analysis. The analysis of data contained in the database will allow to identify mechanisms of accidents, define professional profiles of people injured, establish the most likely scenario of construction industry accident and set out necessary prevention measures. The information received may serve as a basis for setting out preventive actions to be taken in order to improve levels of safety at work in construction industry.

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