

## Research Article

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Mariusz Szóstak\*

# Analysis of occupational accidents in the construction industry with regards to selected time parameters

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**Abstract:** The construction industry is characterized by a large variety and variability of implementation conditions. Construction works are carried out throughout the whole calendar year under varying atmospheric conditions, both during the day and also during the evening and night. Construction workers also often work overtime that exceeds the eight-hour working day. Work in such conditions creates a particularly high threat to the health and life of working people. In the issues of work safety the most important is worker, who in the accident process has a triple role: the decision maker, the perpetrator of an accident and the victim. The purpose of this article is to examine whether there is a dependence between the number of occupational accidents in the construction industry and time parameters such as: the time of an accident, the day of the week and the month in which an accident occurred. The article also attempts to determine the dependence between the age of the injured person, work experience and the number of hours worked by the injured person from the time of starting work to the moment of the accident.

## 1 Introduction

In recent years, a large number of scientific works devoted to the problems of engineering construction processes has involved studies and scientific research that deal with the subject of occupational work safety in the construction industry. This topic covers several research areas, including:

- analysis of the mechanisms of the occurrence of occupational accidents [1, 2],
- analysis of the causes of accidents at work [3–5],

- identification of direct and indirect factors which affect the accident rate [6–8]
- analysis of the accident rate with regards to factors that generate costs [9–11].

In the issues of work safety the most important is worker, who in the accident process has a triple role: the decision maker, the perpetrator of an accident and the injured person, in the worst case, as the victim. Worker as a participant in the investment process is exposed to many dangerous factors that cause accidents. Sometimes worker is the source of these factors [12]. Human causes account for over 65% of all causes accident at work. Failure to use personal protective equipment by an employee, disregard of a danger and inappropriate psychophysical state of an employee due to the consumption of alcohol, drugs or psychotropic substances are the main causes of accidents [13].

The construction industry is characterized by a large variety and variability of working conditions and dangerous employee behaviour. Construction works are carried out throughout the whole calendar year under varying atmospheric conditions, both during the day and also during the evening and night. Construction workers also often work overtime that exceeds the eight-hour working day. Work in such conditions creates a particularly high threat to the health and life of working people.

The purpose of this article is to examine whether there is a dependence between the number of fatal and serious occupational accidents in the construction industry and time parameters such as: the time of an accident, the day of the week and the month in which an accident occurred. The article also attempts to determine the dependence between the age of the injured person, work experience and the number of hours worked by the injured person from the time of starting work to the moment of the accident.

The article was organized in the following way: Section 2 presents a review of the literature related to the topic of the article. Section 3 discusses the sources of information about the injured person in an accident at work, description of the analyzed parameters and the used re-

\*Corresponding Author: Mariusz Szóstak: Wrocław University of Science and Technology, Faculty of Civil Engineering, Department of Construction Technology and Management, Poland, E-mail: mariusz.szostak@pwr.edu.pl

search method. Section 4 contains the results of statistical analysis 630 people injured in occupational accidents in the construction industry and the dependencies between individual parameters using the Spearman rank correlation coefficient. Finally, section 5 is a summary that identifies the most important conclusions.

## 2 Literature review

Studies carried out to date have shown that there are dependencies between changing working conditions and the factors that characterize victims. Investigations of fatal accidents that took place in the years 2001-2005 at construction sites in Taiwan showed a relationship between the size of an enterprise in which the accident took place, work experience and the age of the injured person [14]. Similar studies were carried out in Iran. On the basis of 21 864 people injured in accidents in the construction industry, the existence of a dependence between the examined features was confirmed. These features included, among others, the age of the injured person; the date, time and place of the accident; as well as the causes and consequences of the accident [15].

The analyses carried out on more than 1.1 million occupational accidents in the Spanish construction industry, which took place during 2003-2008, showed an occurrence of dependencies between the effects of occupational accidents in the construction industry and the following parameters: the age of the injured person, the type of conducted work, the size of an enterprise, work experience, the place of the accident, the day of the week, the number of days of absence from work, injuries and the climatic zone [16].

The analysis of 485 people injured in occupational accidents, which took place during 2008-2014 in the Polish construction industry, allowed the impact of the following characteristics on an occupational accident to be examined: the employment status of an injured person, occupation, age, work experience, preparation of an employee to perform duties at a workplace. As a result of the research the authors determined the profile of a person who is the most often affected by an accident in the construction industry [12].

Data analysis and literature studies also showed the existence of a dependence between physiological parameters of the human body, which change in subsequent periods of life, and accidents [17].

## 3 Research methodology

The main body of the supervision and control the principles of occupational health and safety of compliance in Poland is the State Labour Inspectorate (SLI). The State Labour Inspectorate are obliged to investigate the circumstances and causes of fatal and severe accidents. In addition, the District Labour Inspectorate (DLI) keep a record of the circumstances and causes of accidents at work causing minor personal injury and potentially accidental events, although this is not mandatory by law. After the post-accident investigation, a labour inspector draws up the post-accident protocol, in which he includes the conclusions from the investigation. The 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, information on the time and place of the event. Moreover post-accident protocols contain data that characterizes an injured person, namely: sex, year of birth, citizenship, employment status, performed occupation, work experience at an occupied workplace in the plant in which the accident took place, and also preparation for work [18]. In this article the post-accident protocols were the source of information regarding injured people.

Statistical data on the accidents at work which have taken place in the construction industry are collected also by the Central Statistical Office of Poland (CSO). However, the Central Statistical Office of Poland mentioned above has a different set of data on accidents at work than the State Labour Inspectorate (SLI). Each year CSO publishes a report entitled: "Accidents at Work. Statistical Data and Compilations". Data on accidents at work are collected from employers are compiled there in tables. From this source one can learn, e.g., how many persons were injured in accidents, how many persons sustained injuries on building sites and in other places. The statistics contained in the sets were compiled in accordance with the Statistical Accident Card requirements.

On the basis of collected documents regarding occupational accidents in the construction industry that occurred in the years 2008-2017 in selected 5 Polish voivodeships, which were provided by District Labour Inspectorates in Poland, a database of occupational accidents was created. The article investigates 630 occupational accidents that took place in the Dolnoslaskie, Kujawsko-Pomorskie, Lubelskie, Lubuskie and Slaskie voivodships. In this paper only fatal and serious accidents at work have been studied. In the conducted research, the relationships between the following 6 parameters were defined:

1. day of the week,
2. month
3. time of the accident,
4. age of the injured person,
5. work experience of the injured person,
6. number of hours worked by the injured person from the time of starting work to the moment of the accident.

The correlation analysis was used to determine the correlation between the studied parameters, and the Spearman's rank correlation coefficient was used to describe the relationship between the assessed parameters. To interpret the correlation and to determine the degree of dependence of two features ( $r_{xy}$ ), a 7-degree scale was assumed, namely: when  $r_{xy} = 0$ , the variables are not correlated; when  $0 < r_{xy} < 0.1$ , there is a very weak correlation; when  $0.1 \leq r_{xy} < 0.3$ , there is a weak correlation; when  $0.3 \leq r_{xy} < 0.5$ , there is an average correlation; when  $0.5 \leq r_{xy} < 0.7$ , there is a high correlation; when  $0.7 \leq r_{xy} < 0.9$ , there is a very high correlation; and when  $0.9 \leq r_{xy} < 1.0$ , there is almost full correlation [19]. In the conducted research, when interpreting the correlation coefficient, the most important thing was to determine the significance of the correlation, and then to determine its degree. The calculations were performed using the STATISTICA 13 integrated statistical and analytical software package.

## 4 Analysis of statistical data

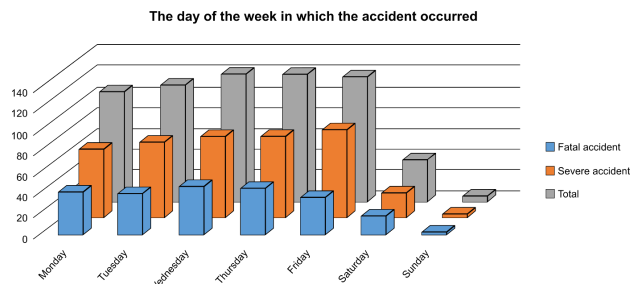
The analysis covered 630 people injured in occupational accidents in the construction industry, including 222 fatal accidents (which accounted for 35.24% of all accidents) and 408 severe accidents (which accounted for 64.76% of all accidents). Table 1 presents the results of the conducted calculations.

### 4.1 Analysis of the day of the week

The structure of people affected in an accident with regards to the day of the week in which the accident occurred is shown in Figure 1 and is as follows:

- fatal accidents most frequently occurred on Wednesdays and Thursdays. The number of injured people was equal to 45 and 44, respectively, and their share was respectively 20.27% and 19.82% of all fatal accidents,

- as many as 85 people suffered from a serious injury on Friday, which amounted to 20.83% of all serious accidents,
- when analyzing all the victims, it should be noted that accidents occurred most frequently on Wednesdays. The number of injured people was equal to 123, and their share in the total number of victims amounted to 20.27%.



**Figure 1:** The day of the week in which the accident occurred [own work]

On the basis of the analyzed data, the common opinion that occupational accidents most often occur at the beginning and end of the average standard 5-day working week cannot be confirmed. As with the analyzes carried out by other researchers [15], [20], the conducted research did not show any relation between the day of the week and the possibility of an occupational accident occurring. Analysis of accidents on particular days of the week showed that their number changes in a small range and oscillates between similar values. The analysis of the collected data does not indicate that the day of the week has an impact on the occurrence of an accident, although there is a slight upward trend in the number of accidents in the second half of the week.

### 4.2 Analysis of the month in which an accident occurred

Figure 2 shows the number of occupational accidents with regards to the month in which the accident occurred. The conducted research confirmed that the number of occupational accidents depends on the so-called construction season, the peak of which is in the third quarter of the year, i.e. from July to October [17], [21]. The analyzed data indicates a greater susceptibility of occupational accidents by employees during summer (33.02%, i.e. 165 occupational

**Table 1:** Summary of data on injured people

Parameter	Category	Number of occupational accidents			% of the number of occupational accidents		
		Total	Fatal	Severe	Total	Fatal	Severe
(1) Day of the week (Modal = Wednesday)	Monday	106	40	66	16,83%	18,02%	16,18%
	Tuesday	112	39	73	17,78%	17,57%	17,89%
	Wednesday	123	45	78	19,52%	20,27%	19,12%
	Thursday	122	44	78	19,37%	19,82%	19,12%
	Friday	120	35	85	19,05%	15,77%	20,83%
	Saturday	41	17	24	6,51%	7,66%	5,88%
	Sunday	6	2	4	0,95%	0,90%	0,98%
(2) Month (Modal = July)	January	28	8	20	4,44%	3,60%	4,90%
	February	37	18	19	5,87%	8,11%	4,66%
	March	36	8	28	5,71%	3,60%	6,86%
	April	54	15	39	8,57%	6,76%	9,56%
	May	57	18	39	9,05%	8,11%	9,56%
	June	54	16	38	8,57%	7,21%	9,31%
	July	74	25	49	11,75%	11,26%	12,01%
	August	68	22	46	10,79%	9,91%	11,27%
	September	66	23	43	10,48%	10,36%	10,54%
	October	69	28	41	10,95%	12,61%	10,05%
	November	55	25	30	8,73%	11,26%	7,35%
	December	32	16	16	5,08%	7,21%	3,92%
(3) Time of accident (Median = 11:35:29 ± 02:53:46)	06:00-06:59	4	2	2	0,63%	0,90%	0,49%
	07:00-07:59	69	22	47	10,95%	9,91%	11,52%
	08:00-08:59	56	17	39	8,89%	7,66%	9,56%
	09:00-09:59	67	18	49	10,63%	8,11%	12,01%
	10:00-10:59	64	23	41	10,16%	10,36%	10,05%
	11:00-11:59	58	20	38	9,21%	9,01%	9,31%
	12:00-12:59	72	20	52	11,43%	9,01%	12,75%
	13:00-13:59	62	28	34	9,84%	12,61%	8,33%
	14:00-14:59	77	28	49	12,22%	12,61%	12,01%
	15:00-15:59	64	31	33	10,16%	13,96%	8,09%
	16:00-16:59	18	10	8	2,86%	4,50%	1,96%
	17:00-17:59	14	3	11	2,22%	1,35%	2,70%
	18:00-18:59	3	0	3	0,48%	0,00%	0,74%
	19:00-19:59	1	0	1	0,16%	0,00%	0,25%
	20:00-20:59	1	0	1	0,16%	0,00%	0,25%
(4) Age of injured person (Modal = 29 years old)	<20	4	1	3	0,63%	0,45%	0,74%
	20-29	192	56	136	30,48%	25,23%	33,33%
	30-39	119	39	80	18,89%	17,57%	19,61%
	40-49	130	43	87	20,63%	19,37%	21,32%
	50-59	155	69	86	24,60%	31,08%	21,08%
	>60	30	14	16	4,76%	6,31%	3,92%
(5) Work experience of injured person	1 day	49	14	35	7,78%	6,31%	8,58%
	1 week	152	46	106	24,13%	20,72%	25,98%
	1 month	225	75	150	35,71%	33,78%	36,76%

(Modal = 1, Median = 182 days)	1 year	362	118	244	57,46%	53,15%	59,80%
	2 years	71	30	41	11,27%	13,51%	10,05%
	3 years	50	23	27	7,94%	10,36%	6,62%
	4-5	41	14	27	6,51%	6,31%	6,62%
	6-10	42	18	24	6,67%	8,11%	5,88%
	11-15	32	7	25	5,08%	3,15%	6,13%
	16-20	25	8	17	3,97%	3,60%	4,17%
	21-25	7	4	3	1,11%	1,80%	0,74%
(6) The number of hours worked by injured person from the time of starting work to the moment of the accident (Modal = 15 min, Median = 4.5h)	00:00-00:59	86	28	58	13,65%	12,61%	14,22%
	01:00-01:59	50	19	31	7,94%	8,56%	7,60%
	02:00-02:59	79	17	62	12,54%	7,66%	15,20%
	03:00-03:59	57	25	32	9,05%	11,26%	7,84%
	04:00-04:59	64	25	39	10,16%	11,26%	9,56%
	05:00-05:59	76	21	55	12,06%	9,46%	13,48%
	06:00-06:59	59	24	35	9,37%	10,81%	8,58%
	07:00-07:59	73	29	44	11,59%	13,06%	10,78%
	08:00-08:59	57	25	32	9,05%	11,26%	7,84%
	09:00-09:59	11	3	8	1,75%	1,35%	1,96%
	10:00-10:59	13	6	7	2,06%	2,70%	1,72%
	11:00-11:59	2	0	2	0,32%	0,00%	0,49%
	12:00-12:59	2	0	2	0,32%	0,00%	0,49%
	13:00-13:59	1	0	1	0,16%	0,00%	0,25%

accidents) when compared to the winter period (16.03%, i.e. 101 occupational accidents). In addition, it was noted that accidents most frequently occurred in the seventh month of the year, i.e. in July.

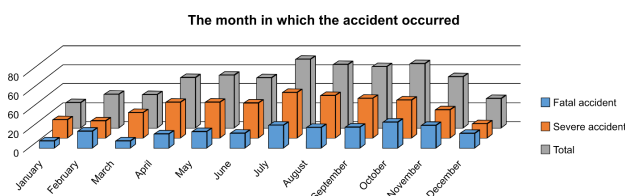


Figure 2: The month in which the accident occurred [own work]

### 4.3 Analysis of the time of the accident

Figure 3 shows the number of occupational accidents with regards to the time at which the accident occurred.

The analysis of the time of the accident allowed the following conclusions to be formulated:

- the course of the distribution of accidents is of a wave nature,
- occupational accidents most frequently occurred in three time intervals, i.e. :

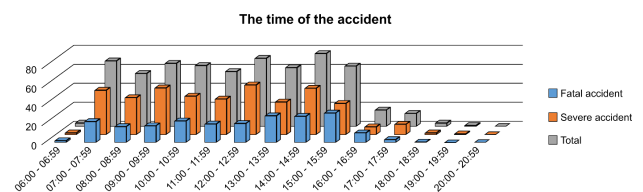


Figure 3: The time of the accident [own work]

- between 07:00-07:59 - the first hour of work which is designated for preparatory activities, i.e. the time required to prepare for work after an employee comes to the workplace (69 injured people, i.e. 15.40% of all accidents),
- between 12:00-12:59 - the time when employees rest and have a lunch break (72 injured people, i.e. 16.07% of all accidents),
- between 14:00-14:59 - the last hour of work intended for the performance of activities that are necessary to complete the work (77 injured people, i.e. 17.19% of all accidents),
- there were no occupational accidents recorded between 21.00 and 05.59 in the conducted research.

#### 4.4 Analysis of the age of the injured person

The age structure of the victims is shown in Figure 4 and is as follows:

- the largest group of people injured in occupational accidents consisted of people aged 20-29. The number of people injured in this age group amounted to 192 people, and their share in the total number of victims amounted to 30.48%. The obtained statistical data showed that in every third accident, a person who is under 30 years old is harmed,
- in second place is the group of people aged 50-59. The share of this group in the total number of people affected during accidents amounted to 24.63%, with the number of victims amounting to 155 persons,
- the most frequent value in the set of analyzed data (modal) was 29 years, and the average age of the injured person was equal to  $39 \pm 13$  years,
- the number of accidents among young employees (aged 20-29) is much higher than in other age groups,
- the severity of the accident increases with the age of the employee. In the group of older workers aged over 50, fatal accidents are more frequent than severe accidents, whereas younger people are most often affected by severe accidents.

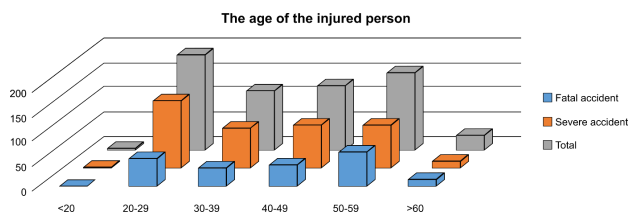


Figure 4: The age of the injured person [own work]

#### 4.5 Analysis of work experience

Figure 5 shows the number of people injured in occupational accidents with regards to their work experience in an enterprise.

The analysis showed that:

- 57.46% of all injured people (i.e. 362 people) were involved in occupational accidents in the construction industry, which occurred in the first year of their work at the occupied workplace,
- up to 49 employees were injured on the first day of their work, which accounted for 7.78% of all injured

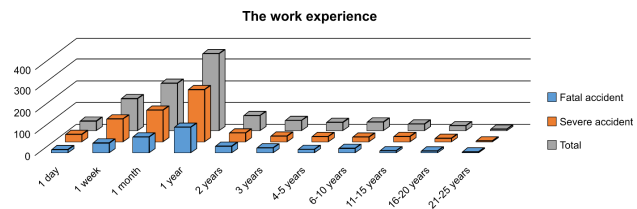


Figure 5: Work experience [own work]

people. Among these employees, 14 people were killed and 35 people were seriously injured.

- 152 people, i.e. 24.13% of all injured people were injured during the first week of their work. From this number, 46 people were injured with a fatal outcome, and 106 people were severely injured,
- 225 people were injured during the first month of their work, which accounted for 35.71% of the total number of victims, of which 75 people died and 150 people were severely injured,
- the longer the work experience at a workplace, the lower the number of accidents,
- the most frequent value in the set of analyzed data (modal) was 1 day, and the average work experience of the injured person was equal to 182 days, i.e. half a year.

The analysis of statistical data showed that people with fewer years of work experience at a workplace - a few days or weeks - most often fall victim to accidents. This is caused by, among others:

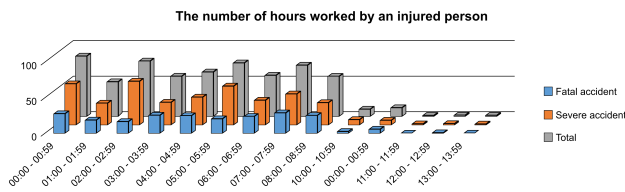
- a lack of or incorrect training in the area of occupational health and safety,
- allowing an employee to work with medical contraindications or without medical examinations,
- insufficient professional preparation of the employee, which is related to the performance of the activity without the required permission,
- ignorance of the provisions and principles of occupational health and safety,
- insufficient focus on the performed activities,
- a lack of experience of the victim.

#### 4.6 Analysis of the number of hours worked by an injured person

Figure 6 shows the number of occupational accidents with regards to the number of hours worked since starting work to the moment of the accident.

The analysis of the time of the accident allowed the following conclusions to be formulated:





**Figure 6:** The number of hours worked by an injured person [own work]

- the accident occurred most often in the first hour of work. The number of injured people amounted to 86, and their share in the total number of victims amounted to 13.65%,
- the same number of injured people were noticed in the group of people who worked overtime that exceeded eight hours of work. As many as 34 people had a fatal accident and 52 people had a severe accident,
- the subsequent places regarding the number of injured people applied to time intervals between the second and third working hour (79 injured people, 12.54%), the fifth and sixth working hour (76 injured people, 12.06%), and also between the seventh and eighth working hour (73 injured people, 11.59%).

## 4.7 Correlation analysis

Table 2 shows the correlation matrix between the analyzed parameters and the calculated Spearman rank correlation coefficients.

In the carried out correlation analysis, no correlation was found for 13 pairs (relations) out of 15 possible, including (1) and (2), (1) and (3), etc. For 13 relations, the Spearman's rank correlation coefficient obtained values within the range  $0 < r_{xy} < 0.1$ , which means a faint or no correlation. Positive correlations were only obtained between the parameters for two relations, i.e. between (3) and (6) and between (4) and (5). The obtained positive correlation means that both parameters increase simultaneously, i.e. the high values of one parameter refer to the high values of the other.

The Spearman's rank correlation coefficient amounted to 0.9660 for parameters (3): time of an accident, and (6): the number of hours worked by the injured person from the time of starting the job until the accident. The obtained correlation coefficient indicates an almost full positive correlation between the analyzed parameters ( $0.9 < r_{xy} < 1.0$ ), which means that there is a strong relationship between the time of the accident and the number of worked hours. The analysis of dependencies showed that accidents most frequently happen in the following hours:

- 07:00-07:59, i.e. in the first hour of work,
- 12:00-12:59, i.e. between the fifth and sixth working hours,
- 14:00-14:59, i.e. in the last hour of work for a standard eight-hour working shift,
- 15:00-20:59, i.e. during overtime hours exceeding the 8-hour working shift.

The Spearman's rank correlation coefficient was equal to 0.3284 for parameters (4): age of an injured person, and (5): the injured person's work experience. The obtained correlation coefficient indicates an average positive correlation between the analyzed parameters ( $0.3 \leq r_{xy} < 0.5$ ). The analysis of dependencies showed that young people (age range between 20 and 29 years) with a small amount of work experience (up to 1 year) are most often affected by accidents. With an increase of age and work experience, the number of occupational accidents decreases.

## 5 Conclusions

This article presents the results of statistical analysis carried out on 630 occupational accidents that took place in Poland in selected voivodeships in the years 2008-2017. In the conducted research, the following dependencies were determined between 6 time parameters: day of the week, month, time of the accident, age of the injured person, work experience of the injured person and the number of hours worked by the injured person from the time of starting work to the moment of the accident.

The dependencies between individual parameters were determined using the Spearman rank correlation coefficient. The study showed a strong correlation between the time of the accident and the number of hours worked, as well as the average correlation between the age of the injured person and work experience. With an increase of peoples' age and their work experience, the number of occupational accidents decreases.

The analysis of people injured in occupational accidents in the Polish construction industry allowed the following conclusions to be formulated:

- the tested parameters influence the number of accidental events to a different degree,
- the day of the week does not affect the possibility of an occupational accident occurring, although there is a slight upward trend in the number of accidents in the second half of the week,

**Table 2:** Spearman's rank correlation coefficients

		Day of the week	Month	Time of the accident	Age	Work experience	Number of hours
		(1)	(2)	(3)	(4)	(5)	(6)
Day of the week	(1)	1,0000					
Month	(2)	0,0237	1,0000				
Time of the accident	(3)	-0,0580	0,0650	1,0000			
Age	(4)	-0,0577	-0,0768	0,0218	1,0000		
Work experience	(5)	0,0127	-0,0461	-0,0197	0,3284	1,0000	
Number of hours	(6)	-0,0550	0,0459	0,9660	0,0326	-0,0052	1,0000

- the analyzed data indicates a greater susceptibility to occupational accidents by employees during summer when compared to the winter period,
- occupational accidents most often occur in three time intervals: between 07:00-07:59, 12.00-12.59 and 14.00-14.59,
- analysis of the age structure of injured people showed that the most common age group of injured employees is those aged 20-29,
- the probability of an accident occurring is the greatest in the first year of work at an occupied workplace when compared to subsequent years of work,
- an accident usually occurs in the first hour of work, as well as during extra hours that exceed the eight-hour working shift.

The determination of the main time parameters and their impact on the occurrence of accidents in the construction industry is the first step to minimize and reduce the number of occupational accidents. According to the author, the conclusions from this study can be used by construction companies in their work safety strategies, as well as in safety training programs. Staff training should be conducted while taking into account the specific needs of each group of employees. Particular attention should be paid to a group of employees with zero or little work experience (up to 1 year). According to the author, some parameters should be further investigated in future research in order to determine other existing significant relationships between the analyzed parameters.

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