WARSAW UNIVERSITY OF TECHNOLOGY Index 351733
FACULTY OF CIVIL ENGINEERING
COMMITTEE FOR CIVIL AND WATER ENGINEERING
POLISH ACADEMY OF SCIENCES ISSN 1230-2945

DOI: 10.24425/ace.2021.138067

ARCHIVES OF CIVIL ENGINEERING

Vol. LXVII ISSUE 3 2021

s. 489–504

Research paper

Influence of the seasons on construction site accidents

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Abstract: The article analyses the changes occurring in accidents in the construction industry in Poland. It was analyzed the influence of the season on the number and structure of accidents. Research and analyzes were carried out on the basis of statistical data, made available by the Central Statistical Office, regarding accidents at work in construction that occurred in the period from 2010 to 2018. The total number of accidents at work in the construction sector in in these years shows a significant downward trend. A similar downward trend can also be seen in individual groups of accidents, broken down into light, serious and fatal. Based on the research carried out, the decisive impact of the season on the accident rates in construction sector was noticed. The smallest value of the accident frequency rate in most of the accident types considered can be observed in the winter season. In turn, the highest value of the light and fatal accident frequency rate can be observed in summer season (July - September). Weather conditions, for example, high temperatures and sunshine can lead to dangerous situations which can result in accidents at work. Climate conditions should therefore play an increasingly important role in assessing the risk of accidents.

Keywords: Accidents, construction industry, employees, season, accident frequency index

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1. Introduction

Construction industry professions are in the group of the most dangerous ones on the labor market. The risk of a fatal accident in construction is three times higher than in other industries [1]. Topics related to safety at work at the construction site have been raised many times in the literature. In [2–6] factors affecting safety at the construction site were analyzed, and the causes of accidents were systematized, listing, among others technical reasons, human errors, improper supervision or organization of work. On the other hand, publications [7–10] focused also on the introduction of accident prevention systems, their supervision and factors that impede the proper application of safety principles. The most numerous group of accidents are falls from a height [11]. However, according to the authors of [4–5] among the causes of all accidents, human errors dominate. Performing construction works involves the exposure of employees to many onerous and even harmful factors as well as a significant level of energy expenditure and stress. Human causes, resulting from the psychophysical state and human behavior, constitute 39.7% of the causes of events that were a deviation from the normal state [12]. The psychophysical state of employees is equally influenced by psychophysical and physical stimuli, e.g. noise, inadequate lighting, too high or too low air temperature, dustiness and radiation. In construction the most numerous group of accidents – falls of workers from heights, is very often associated with work on building scaffoldings. An analysis of 177 accidents on scaffolding in Poland, described in [13], revealed that 27.4% of them were caused by human errors. Human errors are affected by lack of concentration and fatigue [14–15]. In addition, work on the scaffolding is performed in dynamically changing, often uncomfortable and adverse conditions of the external environment [16–17]. Too high or too low temperature, high humidity, high and low atmospheric pressure, changes in wind speed in connection with work requiring constant physical exertion can cause changes in the body even in people who acclimated [18]. It has been shown that construction accidents were influenced by weather factors such as temperature and humidity [19]. In our climate, the factors of the external environment are related to the seasons.

The earlier studies also revealed the influence of the season on accidents in the construction industry. In the Soviet Union, for example, in 1977–1985, more accidents occurred during autumn than in the rest of the year [20]. According to the authors of the paper [21] analyzing 1639 accidents, it was observed that low pressure caused twice as many accidents at work as high pressure. The number of accidents also increased significantly in autumn and spring. In Singapore the highest number of fatal accidents in construction industry occurred in October before the rainy

season [22]. In Taiwan, on the other hand, between 2000 and 2009, the most accidents were during the summer and were mostly workers from 21 to 60 years old [23]. The number of accidents in 2002–2011 in South Australia was the highest in the autumn, but the association between the season and the severity of injuries could not be established [24]. Based on the Survey of Occupational Injuries and Illnesses (SOII) in the United States between 2003 and 2010, most injuries happened during the summer months [25]. The accidents in Korea, for example, were less frequent in winter than in other seasons [26]. The impact of the period of the year was also analyzed in China [27]. It was observed that the month with the highest average number of accidents was August (2010–2016).

The purpose of the research was to analyze changes occurring in accidents in construction in Poland and to attempt to assess the impact of the season on accidents. Research and analyzes were carried out on the basis of statistical data, made available by the Central Statistical Office, regarding accidents at work in construction that occurred in the period from 2010 to 2018. To assess the accident rate following accident indicators were used: number of people injured in accidents at work and accident frequency rate.

2. Methods

Paper sent Public statistics in Poland is a system for collecting, storing and processing statistical data, as well as for announcing, sharing and disseminating it. The Central Statistical Office (GUS) collects information about the inhabitants of Poland, the environment, conditions, life, education, culture, work, finances, etc. The data is collected by interviewers, completion and sending statistical reports and using administrative sources. Data are most often compiled in tabular form and are available at www.stat.gov.pl. It is also possible to order statistical data. The most important data, especially from the perspective of the economy and country management, are published monthly or quarterly – in the form of short announcements, studies and publications. Part of the data is compiled and published once a year.

In this article, statistical data on accidents in construction was prepared by the Central Statistical Office on request. The information provided included the number of victims of accidents at work in construction in each month from 2010 to 2018, broken down into light, serious and fatal accidents.

According to the definition given in the Act (Dz. U. poz. 1773, 2017) [28], an accident at work is an emergency, caused by an external factor causing injury or death, which occurred in connection with work:

- during or in connection with the employee's regular activities or superiors' orders,
- during or in connection with the employee's work for the employer, even without particular orders,
- while the employee is at the employer's disposal on the way between the employer's headquarters and the place where the work has to be performed according to the contract.

A fatal accident at work is an accident that resulted in the death of the injured person at the scene of the accident or within 6 months of the accident. A serious accident at work is an accident which results in serious bodily injury, namely: loss of vision, hearing, speech, reproductive capacity or other bodily injury or health disorder, violating the basic functions of the body, as well as an incurable or life-threatening disease, permanent mental illness, permanent, complete or significant inability to work in a profession, or permanent serious disfigurement or deformation of the body. A light accident is an accident causing inability to work for no more than 28 days.

Works on construction sites last all year, although due to weather conditions their scope in winter is more limited than in other seasons. Due to the fact that the statistical data were prepared with an accuracy of one calendar month, in the research a simplification was applied – the principle that each season of the year corresponds to full months. Although this slightly differs from reality, it does not significantly change the results of the analysis. It was assumed that the following seasons correspond to the following months: winter – January, February, March; spring – April, May, June; summer – July, August, September; autumn – October, November, December.

In the analyzes carried out, the following indicators were used to assess the accident rate:

- the number of people injured in accidents at work during the first year, broken down into light, serious and fatal accidents as well as the total number,
- light, serious, fatal and total accidents frequency index, defining the number of injured persons in the examined period per every 1000 employed people.

The accident frequency index was calculated according to the formula:

$$w_w = \frac{n_w}{n_p} 1000 \tag{2.1}$$

where:

n_w – the number of injured persons in the examined period of time, n_p – the average number of employed people in the examined period of time.

Average number of employed in a quarter was calculated as the arithmetic mean of two values: at the end of the previous and current quarter, e.g. the average number of employees in the II quarter was calculated as the arithmetic mean of the number of employees at the end of the I and II quarter. The number of employed persons, regards units of the national economy excluding economic entities employing up to 9 persons. It does not embrace, employed on social, political and trade union organisations and employed in the scope of national defence and public safety [29].

3. Results

3.1. Impact of the number of employees and the price index of construction and assembly production on accident rates

In individual sectors of the economy, accident rates are analyzed and assessed in terms of the number of employees. However, it should be noted that phenomena such as accidents at work are also significantly influenced by the pace of work [30], which translates into the value of production achieved. To assess whether there is a relationship between these factors, an analysis was made of changes in the number of people employed in construction and the price index of construction and assembly production in the years 2010–2018. For this purpose, publicly available data on the number of employees (Central Statistical Office) [29] and on sales of construction and assembly production (Central Statistical Office) [31] were used.

Fig. 1a shows in thousands the number of people employed in construction at the end of the fourth quarter of each year. Fig. 1b shows in millions of PLN the value of sales of construction and assembly output realized in the country for construction entities in the years 2010–2018. The purpose of the analysis is to obtain information as to whether and to what extent the accident rate in construction depends on the number of employees and the construction output price indices. Fig. 2 presents in millions of zlotys per 1 person employed in construction the price index of sold construction and assembly production for construction entities in the examined period of time. This price index, in individual years, varies in a small range from 0.183 to 0.240 million PLN/person. On this basis, it can be assumed that these two factors, namely: the number of persons employed in construction and the price index of construction and assembly production, affect the accident rate in construction to a similar degree. The correlation between these factors was also verified. The calculated value of the Pearson linear correlation coefficient is 0.567 and is in the range from 0.44

to 0.6. This means that there is a positive linear relationship at moderate level. Further analyzes regarding accident rates in construction took into account only the number of employees.

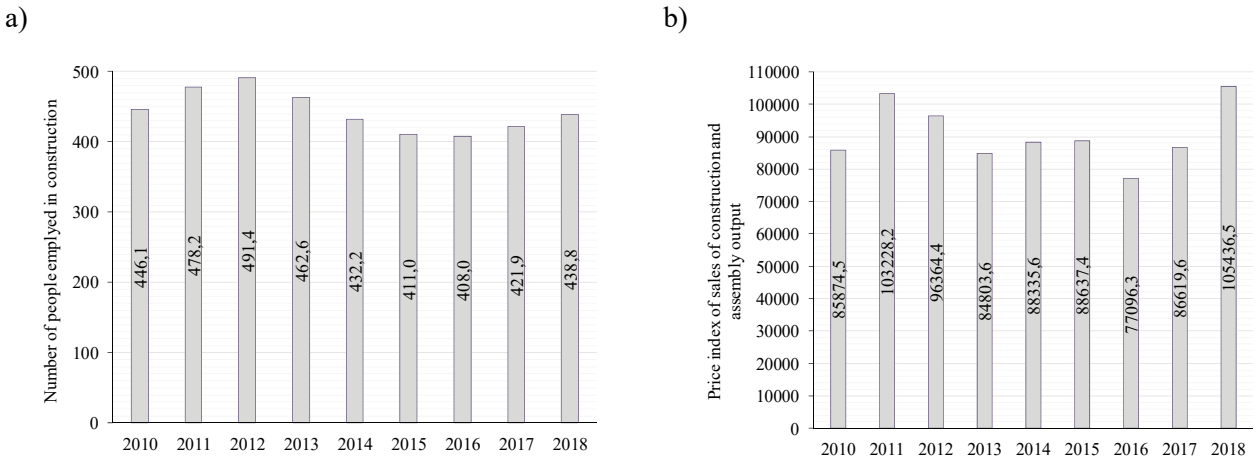

Fig. 1. a) Number of people employed in construction, b) Price index of sales of construction and assembly output

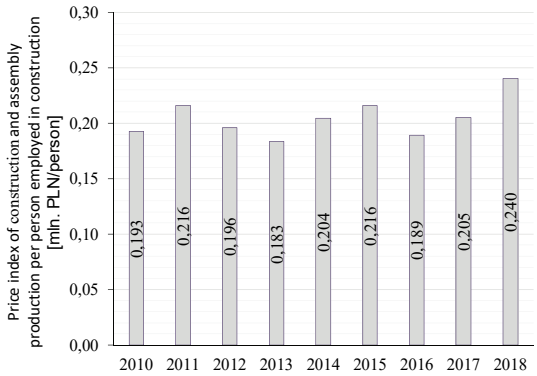

Fig. 2. Price index of construction and assembly production per person employed in construction

3.2. Analysis of changes in the number of accidents at work in construction

Fig. 3a presents a chart with changes in the total number of people injured in accidents at work in construction in the years 2010–2018 [32]. A significant downward trend can be noticed in this phenomenon (dashed line). In 2010, the number of all reported accidents on construction sites in Poland was slightly lower than in 2011 and involved 9098 people, while in 2011 accidents involved 9222 people. In 2018, 5247 accidents were registered, i.e. 42% less compared to 2010 and 43% less compared to 2011. The data presented in Fig. 3b [32] show that the number of persons injured in light

accidents decreased by as much as 42%, from 8849 in 2010 to 5114 in 2018. Similarly, in case of serious accidents, the number decreased by 37% from 135 in 2010 to 85 in 2018. In turn, the number of people injured in fatal accidents decreased in the same period by 58% from 114 in 2010 to 48 in 2018 (Fig. 3d). However, it should be noted, that in 2015 and 2017 the number of people injured in serious and fatal accidents increased compared to the year before. Changes in the accident rate are very well represented by a trend line in the form of a 4rd degree polynomial with a 0.99 R^2 coefficient of determination (Fig. 3a). A similar tendency can be noticed in case of light accidents for which a high value of the coefficient of determination equal to 0.99 was obtained using the trend line in the form of a 4rd degree polynomial (Fig. 3b). In the case of serious and fatal accidents, the ascending – decreasing tendency is also well described by the 4rd degree polynomial with 0.91 (Fig. 3c) and 0.95 (Fig. 3d) coefficients of determination for serious and fatal accidents, respectively.

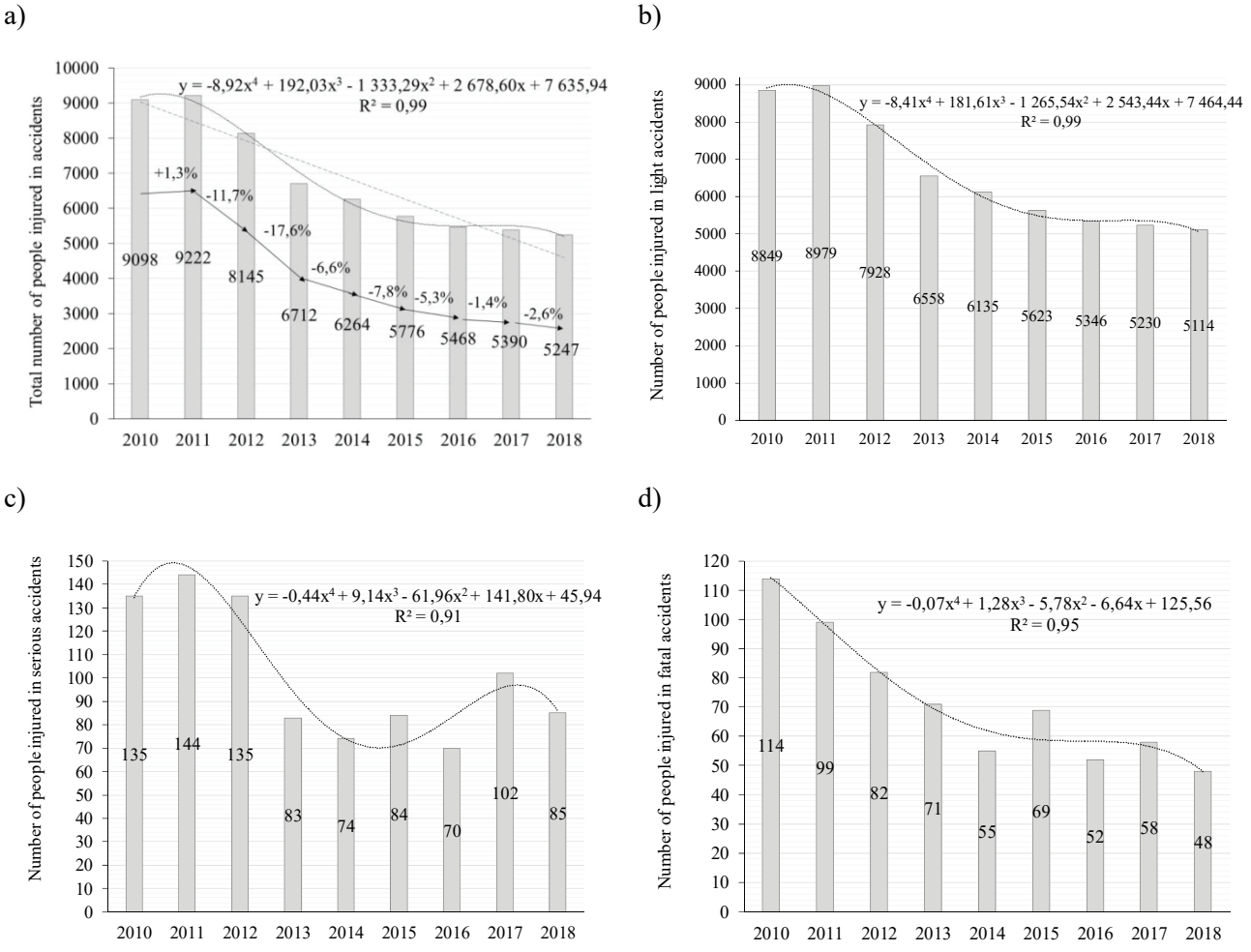

Fig. 3. Number of people injured in: a) total accidents, b) light accidents, c) serious accidents and, d) fatal accidents in construction in Poland in the years 2010–2018

3.3. Analysis of the influence of the season on the number of accidents

In order to analyze the influence of the season on the number and structure of accidents, the calendar year was divided into quarters roughly coinciding with the seasons. Fig. 4 presents the evolution of the total number of people injured in accidents at work in construction in individual quarters of the subsequent years of the examined time period [32].

The smallest number of people injured can be observed in the winter season which according to the adopted division is the time from January to March. In turn, the largest number of people injured can be observed in summer season (July–September). In spring and autumn, the accident rate is between levels achieved in winter and summer (except 2016).

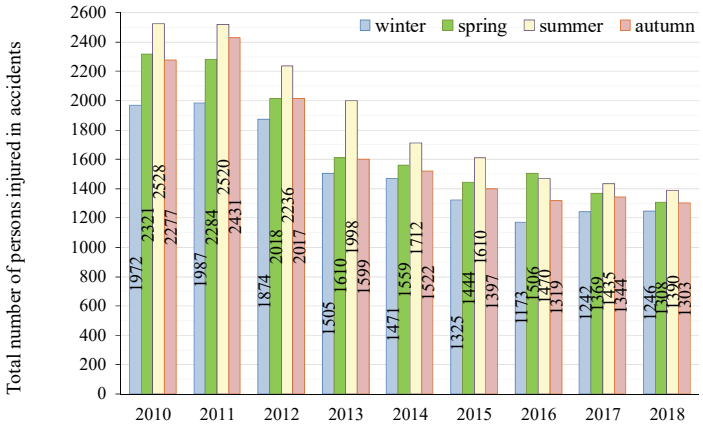

Fig. 4. Total number of persons injured in accidents at work in construction in individual quarters of the year in the years 2010–2018

In the analyzes carried out, the accident rate in construction was also characterized by the accident frequency index defining the number of injured persons in the examined period per every 1000 employed people. Fig. 5a presents the total accident frequency index for individual quarters of the examined time period. Like the number of people injured in accidents, the accident frequency index also reaches its highest value during the summer season. The exception is 2016, when the highest value of this indicator was observed in the spring season.

Fig. 5b, 5c and 5d show the development of the accident frequency index of light, serious and fatal accidents. Distribution of light accident frequency index (Fig. 5b) indicators in the following examined years is a reflection of the distribution of the total number of accident frequency index (Fig. 5a). In the individual years studied, the highest value of this indicator was recorded in the summer of 2010 and it was 5.67 people injured per 1000 employed people. The lowest value of

the frequency index of light accidents was recorded in the winter of 2016 and it was 2.79 people injured per 1000 employed people (Fig 5b).

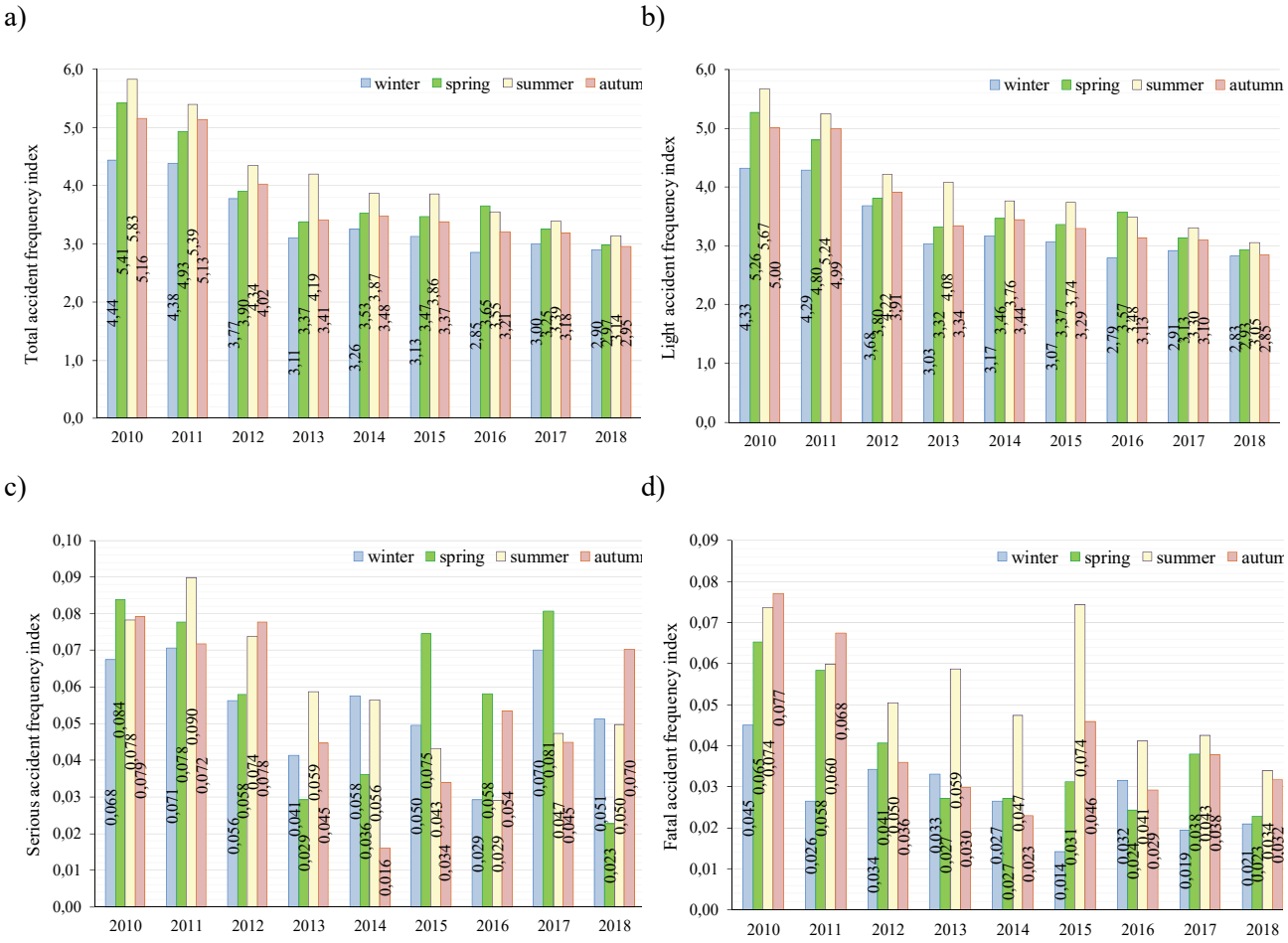

Fig. 5. The frequency index of a) total accidents, b) light accidents, c) severe accidents and d), fatal accidents in the construction in individual quarters of the year in the years 2010–2018

The previously observed regularity regarding the highest value of the total accident frequency index in the summer season and the lowest in the winter season (Fig. 5a) differs from the frequency index of serious accidents (Fig. 5c). In this case, in each of the examined years, the season of the year in which the highest value of this indicator was noted changes. In 2010, 2015, 2016 and 2017, the highest value of the frequency index of serious accidents was recorded in the spring season. In 2011 and 2013 only, the highest value of the serious accident frequency index was recorded in the summer season. In turn, the highest value of the frequency index of serious accidents in 2012 and 2018 was recorded in the autumn season, while in 2014 in the winter season. The highest value of this indicator was observed at 0.090 in summer 2011.

Other observations relate to the value of the fatal accident frequency index presented in Fig. 5d. In 2010 and 2011, the highest value of this indicator was recorded in the autumn, and in the years 2012–2018 in the summer season. In 2015, in comparison to previous years, the frequency index of fatal accidents decreased significantly in the first quarter (winter), while it increased significantly in the summer season, equalizing the level of 2010. In the years 2013–2018, fewer fatal accidents were recorded in spring than in the years 2010–2012. The high frequency index of fatal accidents in summer during the last few years (2012–2018) is worrying. This may be related to, among many, to global warming and increasing number of days when construction workers are exposed to uncomfortable thermal conditions.

4. Discussion

Accidents in construction depend on many factors of economic, legislative, management, technical, environmental and human nature [33–34]. These factors generate various hazards and cause that the accident rate assessed through the prism of the number of people injured in accidents at work, the number of people employed, the structure of accidents and the frequency of accidents, changes over time.

The article presents the development tendency of the accident phenomenon in construction in Poland, estimated by the number of people injured in light, serious and fatal accidents at work. For each phenomenon studied, a trend function was developed in the form of an n degree polynomial. The simplest mapping of the development trend is the first degree polynomial - the linear function. The number of people injured in accidents in construction reflected by the linear function shows a favorable decreasing trend in the examined time period. However, due to the noticeable variability in the following examined years a fourth degree polynomial is a very good mapping of the development trend. Trend line trends indicate increases and decreases in the number of people injured in accidents due to the influence of previously unknown factors [35]. The results obtained in this work also confirm the research carried out by other authors. For example, a similar upward and downward trend in relation to accidents in construction in Poland was also noted in the works [12, 35]. Due to the longer period of time analyzed, such a tendency has been better visualized, and the trend line reflecting the total number of people injured in construction is created in the abovementioned study by a sixth degree polynomial. It was also noted that this phenomenon observed over the period of about 10 years repeats.

Analysis of trends in accident in construction has been the subject of research by many authors. Such analyzes concerning various aspects can be found, among many, in [36-38]. The accident

phenomenon has a negative impact on the economy, employers, employees and their families and is a serious public health problem in the world [1]. For this reason, it is necessary to observe trends in accidents at work to properly shape the policy of changes in labor law and accident prevention.

The variability of the values of the analyzed indicators in individual quarters of subsequent years proves the simultaneous impact on the accident rate of many different factors, which can be classified as known, hidden, as well as unidentified [39]. Based on the research carried out, the decisive impact of the season on the accident rates in construction was noticed. Figure 6a–6d show the share of the frequency index of total, light, serious, and fatal accidents in the construction between 2010 and 2018 for each season.

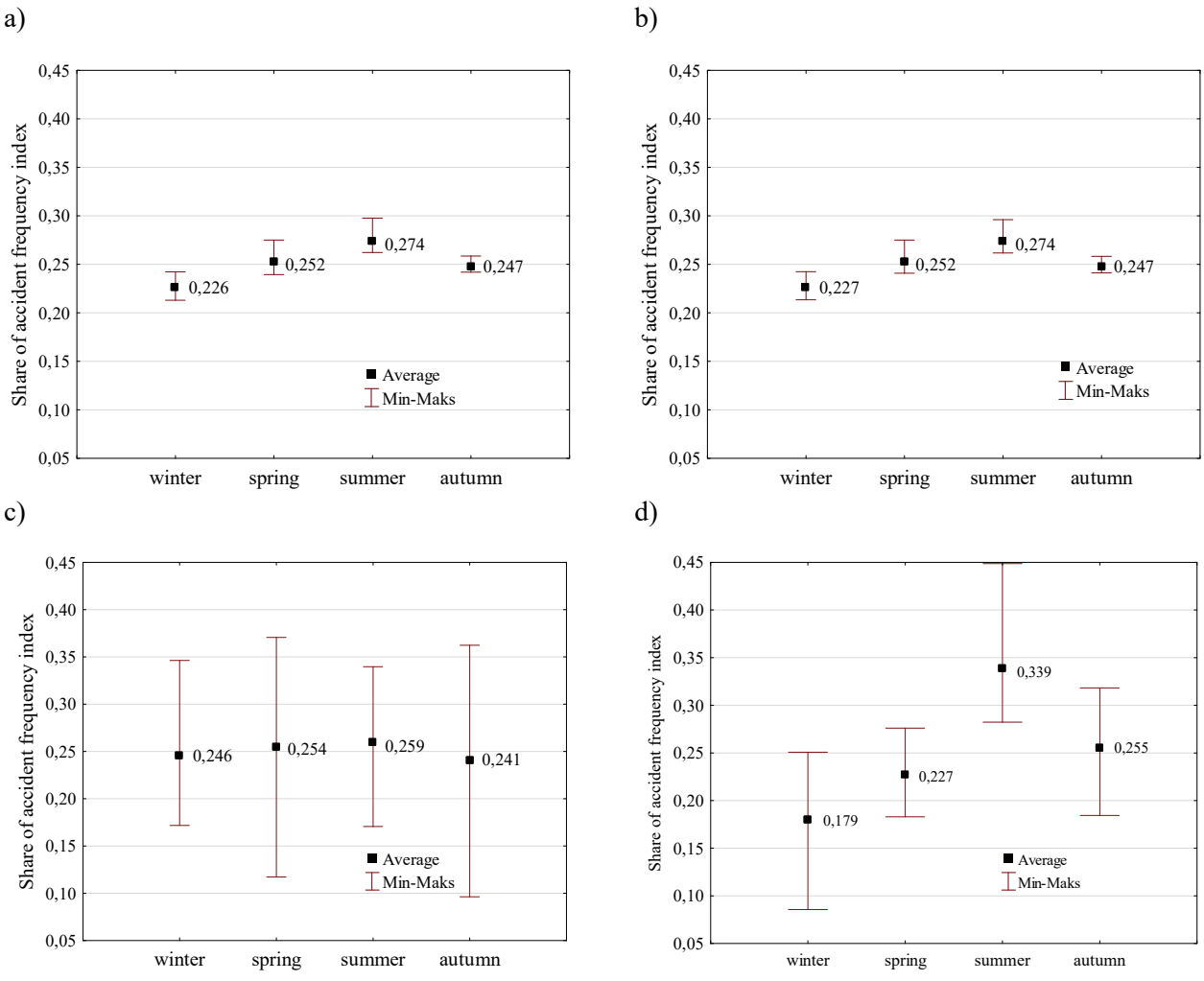

Fig. 6. The share of the frequency index of a) total accidents, b) light accidents, c) severe accidents and d) fatal accidents in construction between 2010 and 2018 for each season

The total number of people injured in accidents and classified as light, serious and fatal, as well as the relevant accident frequency index indicate that the lowest accident rate, with few exceptions,

occurs during the winter season. The average value of the share of the frequency rate of total, light, and fatal accidents is also lowest in winter. Only the average value of the share of the frequency rate of severe accidents is lowest in the autumn. In winter, the number of investments in the construction sector is smaller, and therefore fewer people perform dangerous work. The environment in which construction works take place also has an impact on the accident rate. In winter, there are no heats that can disturb the concentration of employees and contribute to the dangerous behavior of employees. Additionally, during this period, work outside the building is somewhat limited, including works at heights with high accident rates. The highest number of accidents can be observed in the summer season (July–September). Summer time allows to perform outdoor works, and thus works at height (e.g. on scaffolding). High temperatures and high insolation may additionally reduce concentration and fatigue [17–18]. This fact was also noted in the work [40] in which the construction site was classified as a work place where in the summer season workers are exposed to hot environment. In addition, in the work [41] it was indicated that as much as 41.1% of the surveyed construction workers characterized the work environment in construction as changing – cold–hot.

Among the total number of accidents at work in construction in Poland, the largest group are accidents classified as light. They account for 97.03 to 97.94% of all accidents. Serious accidents rank second, accounting for 1.18 to 1.89% of all accidents. Luckily, fatal accidents are the least numerous group and account for 0.88 to 1.25%. American researchers have noted that accidents that result in injury to a working person are always accompanied by a number of potentially accidental events that do not end in injury [42–43]. According to Heinrich, for every single accident resulting in a serious injury or death, there are 29 accidents with minor injuries and 300 accidents without injuries, i.e. potentially accidental incidents. According to Bird, for each serious or fatal accident, there are 10 accidents classified as light and 630 potentially accidental events generating only material losses (Fig. 7). In Poland, according to research conducted by the authors, there are from 32.69 to 47.56 light accidents to 1 fatal accident or one causing a serious injury. However, state statistics do not contain information about potentially accidental events. For this reason, the results of these studies cannot be quoted.

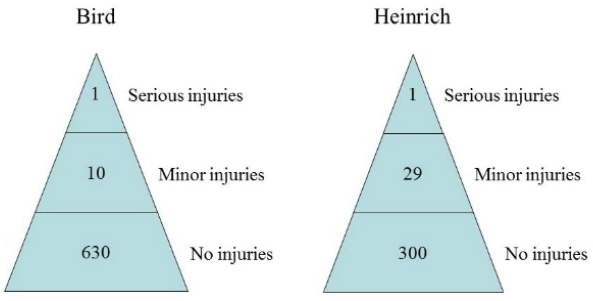

Fig. 7. Accident triangle according to Heinrich, Bird

5. Conclusion

Systematically tightened up the health and safety regulations, more and more frequent inspections of their compliance, increasing the awareness of people working on construction sites of the causes of accidents resulted in the reduction of the total number of accidents in the construction sector in the years 2010–2018. In 2010, 9098 people were involved in accidents, and in 2018, 5247 people were involved in accidents. The influence of the seasons on accident rates in construction is evident in the overall analysis of accidents in the construction sector. The total and light accident frequency index indicates that the highest number of people injured in accidents with the exception of 2016 occurs during the summer months, July–September. The highest value was observed in the summer of 2010 with 5.83 injured persons per 1000 construction workers. The frequency index of fatal accidents between 2012 and 2018 also reaches the highest values in each year during the summer season. In case of the frequency index of severe accidents, such a trend is not observed.

In Poland, according to the research carried out by the authors in the years 2010–2018, share of the frequency index of total accidents in construction in the months July - September averaged 0.274, while for fatal accidents, the worst one, it was 0.339.

Weather conditions, i.e. high temperature, sunlight, which contribute to the increase of fatigue caused by physical effort, lowering concentration and lengthening reaction time are of great significance. These factors can lead to dangerous situations that can result in accidents at work. The changing climate with more frequent and longer lasting heatwaves can additionally cause an increase in the risk for people working on construction sites, and as a consequence increase the number of accidents, especially the worst – fatal ones in the summer season. The period with the lowest accident rates in most of the accident types considered is winter. The share of the frequency index of all accidents in construction from 2010 to 2018 during the months of January through March averaged 0.226. At this time, outdoor work is limited, and thus work at height, which constitute the largest group of accidents at construction sites. Climate conditions should therefore play an increasingly important role in assessing the risk of accidents. The installation of equipment to monitor outdoor environmental parameters at construction sites could also be considered. This could reduce the number of accidents associated with climate impacts.

Acknowledgements:

The paper has been prepared as a part of the project supported by the National Centre for Research and Development within Applied Research Programme (agreement No. PBS3/A2/19/2015

"Modelling of Risk Assessment of Construction Disasters. Accidents and Dangerous Incidents at Workplaces Using Scaffoldings").

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Wpływ pór roku na wypadkowość w budownictwie

Słowa kluczowe: wypadki; przemysł budowlany; pracownicy; pory roku; wskaźnik częstotliwości wypadków

Streszczenie:

W artykule przeanalizowano zmiany zachodzące w wypadkowości w budownictwie w Polsce. Oceniono wpływ pory roku na liczbę i strukturę wypadków. Badania i analizy przeprowadzono na podstawie danych statystycznych, udostępnionych przez Główny Urząd Statystyczny, dotyczących wypadków przy pracy w budownictwie, które wystąpiły w latach 2010–2018. Ogólna liczba wypadków przy pracy w budownictwie w tych latach wykazuje znaczącą tendencję spadkową. W 2010 roku uległo wypadkowi 9098 osób, a w 2018 roku 5247 osoby. Na podstawie przeprowadzonych badań stwierdzono wpływ sezonu na wypadkowość w budownictwie. Wskaźnik częstości wypadków ogółem oraz wypadków lekkich wskazuje, że największa liczba osób poszkodowanych w wypadkach z wyjątkiem roku 2016 występuje w miesiącach letnich, lipiec–wrzesień. Najwyższą wartość zaobserwowano w lecie 2010 roku i wyniosła ona 5.83 osób poszkodowanych na 1000 pracujących przy pracy w budownictwie. Wskaźnik częstości wypadków śmiertelnych pomiędzy 2012 rokiem a 2018 również osiąga największe wartości w poszczególnych latach w porze letniej. W przypadku wskaźnika częstości wypadków ciężkich takiego trendu nie obserwuje się. W Polsce, wg przeprowadzonych przez autorów badań w latach 2010–2018 udział wskaźnika częstości wszystkich wypadków w miesiącach lipiec – wrzesień wyniósł średnio 0,274, natomiast w przypadku wypadku śmiertelnego, tego najgorszego 0,339. Duże znaczenie mają tutaj warunki pogodowe, czyli wysoka temperatura, nasłonecznienie, które przyczyniają się do spotęgowania zmęczenia wywołanego wysiłkiem fizycznym, obniżeniem koncentracji i wydłużeniem czasu reakcji. Czynniki te mogą prowadzić do stworzenia sytuacji niebezpiecznych, których skutkiem mogą być wypadki przy pracy. Zmieniający się klimat z coraz częściej występującymi i dłużej trwającymi falami upałów może dodatkowo powodować wzrost zagrożenia dla osób pracujących na budowach, a w konsekwencji zwiększać liczbę wypadków szczególnie tych najgorszych – śmiertelnych w okresie letnim. Okresem o najmniejszej wypadkowości w większości rozważanych rodzajów wypadków jest zima. Udział wskaźnika częstości wszystkich wypadków w latach 2010–2018 w miesiącach styczeń–marzec wyniósł średnio 0,226. W tym czasie ograniczone są prace na zewnątrz, a tym samym prace na wysokości, stanowiące największą grupę wypadków na budowach. Warunki klimatyczne powinny więc odgrywać coraz większą rolę w ocenie ryzyka wypadków. Można by również rozważyć instalację urządzeń do monitorowania parametrów środowiska zewnętrznego na placach budowy. Mogło by to przyczynić się do zmniejszenia liczby wypadków związanych z oddziaływaniem klimatu.

Received: 2021-01-07, Revised: 2021-03-06