**ARCHIVES OF TRANSPORT** *ISSN (print): 0866-9546*
*Volume 58, Issue 2, 2021* ***e-ISSN (online):*** *2300-8830*
***DOI:*** *10.5604/01.3001.0014.8970*

# ANALYSIS OF THE CAUSES AND EFFECTS OF CYCLIST-PEDESTRIAN ACCIDENTS IN BIGGEST POLISH CITIES

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## *Abstract:*

*Traffic incidents between pedestrians and cyclists result in an incomparably smaller number of victims (injured and killed) than accidents between unprotected traffic participants and other vehicles. However, such incidents cannot be underestimated, as in most cases they take place on elements of infrastructure designed for pedestrians and cyclists, and thus negatively affect the sense of safety of users in places where they should not only feel safe but also comfortable. This paper presents an analysis of such traffic incidents, aimed at recognizing the share of pedestrians and cyclists as perpetrators and also victims of accidents. Three research hypotheses were examined: that the type of infrastructure and also light and weather conditions influences the structure of perpetrators and victims, that the proportion of accidents between pedestrians and cyclists caused by pedestrians is increasing, and that the proportion of victims of accidents between pedestrians and cyclists in the pedestrian group is decreasing. Analyses were performed based on the number of traffic incidents involving cyclists and pedestrians in the six largest Polish cities, registered in the Police Accident and Collision Records System. A total of 1,702 incidents involving 1,034 injured and killed people in years 2007-2018 were considered. Each traffic incident was considered individually, taking into account changes in perpetrator and victim proportions depending on the type and purpose of the infrastructure and external conditions, as well as variability of these proportions over subsequent years. The tools of mathematical statistics were used, including – among others - significance tests for independent proportions and Chi-squared test for trend. On the basis of the conducted statistical analyses, all research hypothesis were proved. It also confirmed that although the proportions are changing, there are still much more traffic incidents are caused by cyclists, but more victims are in group of pedestrians. The results of the research confirm the need to take action to develop effective mechanisms of mutual interaction between pedestrians and cyclists. Especially in view of the growing bicycle traffic in Polish cities.*

***Keywords:*** *traffic accident, perpetrator of traffic incident, vulnerable traffic user*

## *To cite this article:*

*Bauer, M., Okraszewska, R., Richter, M., 2021. Analysis of the causes and effects of cyclist-pedestrian accidents in biggest Polish cities. Archives of Transport, 58(2), 115-135. DOI: https://doi.org/10.5604/01.3001.0014.8970*

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## 1. Introduction

Traffic incidents between pedestrians and cyclists are characterized by much milder effects than similar incidents of unprotected road users with motor vehicles (Ghasemlou, Aydin & Yildirim, 2015) (Bąk, Cheba, & Szczecińska, 2019)(O'Hern & Oxley, 2019)(Meredith, Kovaceva, & Bálint, 2020). A significant proportion of such incidents results more in inconvenience to their participants than the physical effects of accidents. It is also important to note that only a relatively small number of accidents between pedestrians and cyclists result in death or serious injury of the participants (Olszewski et al., 2019)(Graw & König, 2002).

However, this does not mean that traffic incidents of this kind can be underestimated. Incidents between pedestrians and cyclists often take place in spaces where both groups of users should feel not only safe but also comfortable. Both pedestrians on the pavement and cyclists on a separate bicycle road have the right to expect that they will not take part in an incident with another traffic participant (Welsh Government, 2014). All the more so, as the transport policies of European countries (Budzynski, Jamroz, Kustra, Michalski, & Gaca, 2017) and cities (Behrendt, 2019) indicate quite clearly the need to increase non-motorized traffic, i.e. mainly cycling and walking (NACTO, 2016). Especially since there are already effective methods of measuring bicycle and pedestrian traffic (Pogodzinska, Kiec, & D'Agostino, 2020). Without the implementation of such infrastructural solutions it will not be possible to effectively reduce the share of cars in journeys, including areas, where further development of the road system is not possible (Okraszewska, Jamroz, Bauer, Birr, & Gobis, 2017). Therefore, an independent, comfortable cycling infrastructure (Marrana & Serdoura, 2018) is gradually developed and supplemented (Okraszewska, Grzelec, & Jamroz, 2016), also more and more often attention is paid to the completeness and quality of pedestrian routes, which no longer perform only transport functions, and more and more often become an important element of urban spaces.

Unfortunately, a side effect of this most anticipated increase in non-motorized traffic is the problem of the traffic incidents between the two groups of traffic users mentioned, including accidents (Turner, Roozenburg, & Francis, 2006). Bearing in mind the further growth of non-motorized traffic, especially cycling, which is starting to become more and more visible and useful in Polish cities (Bauer, Dźwigoń, & Okraszewska, 2018; Okraszewska, Birr, Gumińska, & Michalski, 2017) - all possible efforts should be undertaken, so that the growth takes place in the most harmonious and safe way possible (Haworth, Schramm, & Debnath, 2014). Also at the level of relations between cyclists and pedestrians, as it is extremely important, that those groups can safely and comfortably coexist in a common urban space (Kiyota, Vandebona, Katafuchi, & Inoue, 2000) and (Gkekas, Bigazzi, & Gill, 2020), including places where the cycling and pedestrian infrastructure meets each other (Hatfield & Prabhakharan, 2016).

For this to be possible, the scale of the problem must be known and the causes and consequences of accidents between cyclists and pedestrians must be identified. Therefore, this paper discusses the results of analyses of the share of perpetrators and victims of incidents between pedestrians and cyclists depending on the type of infrastructure, weather conditions and time of day. The dynamics of increase in the number of such accidents were taken into account - because it will be of key importance for further development of cycling infrastructure and changes in traffic organization, taking into account changing transport needs and behaviors.

There is a rich literature on accidents involving unprotected participants of road traffic. Scientific publications mainly deal with the problems of identifying the causes (Cripton et al., 2015; Malta et al., 2011), (Pazdan, 2020) and consequences of accidents involving pedestrians and cyclists, e.g. (O'Hern & Oxley, 2019), (Turner et al., 2006), (Li, Xiong, Li, Liu, & Zhang, 2015) and (Grzebieta, McIntosh, & Chong, 2011), there is also a significant group of publications devoted to modelling the mutual relations between bicycle and pedestrian traffic, e.g. (Alsaleh & Sayed, 2020), (Nikiforiadis, Basbas, & Garyfalou, 2020) and (Jacyna, Wasiak, Kłodawski, & Gołębiowski, 2017), including accidents (Eriksson, Forsman, Niska, Gustafsson, & Sörensen, 2019) and (Reade & Rich, 2016). However, the vast majority of publications concern accidents with other vehicles, while the problem of traffic incidents between pedestrians and cyclists is most often overlooked due to the smaller negative effects of such incidents. This paper aims to fill this research gap.

## 2. Objectives of the paper

The main aim of the paper is to get to know the structure of perpetrators and victims of incidents between cyclists and pedestrians in the largest Polish cities. It has been recognized, that it is in the largest cities that the biggest transport problems exist, which results from the number of journeys made, and especially their density in downtown areas - especially during peak periods. It is also in the largest cities that there are the greatest problems in finding a place to further develop the infrastructure for individual transport subsystems, which results in social tensions and the need to find not always optimal compromise solutions. It is, after all, in the largest cities that the density of sources and destinations forces frequent intersections of travel routes made by different means of transport, which in turn causes traffic conflicts, incidents and accidents - involving pedestrians and cyclists.

As already mentioned in Chapter 1, the structure of perpetrators and victims would be incomplete without taking into account the variability in time, i.e. in subsequent years of growth in the number of bicycle trips. Therefore, three research hypotheses have been identified:

- the type of infrastructure and light/weather conditions influences the structure of perpetrators (and victims) of incidents (and accidents) between cyclists and pedestrians,
- the proportion of accidents between pedestrians and cyclists caused by pedestrians is increasing, but still the share of perpetrators in the group of cyclists is dominant,
- the proportion of victims of accidents between pedestrians and cyclists in the pedestrian group is decreasing, but pedestrians are still more often victims.

This paper attempts to test the above research hypotheses, based on the methodology described in the next chapter.

## 3. Research method

The research methodology was based on an in-depth analysis of incidents between pedestrians and cyclists in the six largest Polish cities. These are cities with more than 450K inhabitants. According to official statistics gathered by Statistics Poland ("GUS - Bank Danych Lokalnych," n.d.), there are almost 5 million inhabitants of Poland in these cities, although most likely these numbers are understated. However, the number of actual users of these cities is much higher, the urban infrastructure is also used by people who visit the city on a regular and occasional basis, including residents of neighboring municipalities, who make daily trips mainly for work and study in secondary and higher education schools. Those cities differ in the length of cycling infrastructure, as well as in the share of cycling in the modal split - as shown in Table 1.

The shares of bicycle traffic were determined on the basis of Comprehensive Travel Studies carried out in five of the six analyzed cities. Surveys were carried out at different times (years: 2015-2018) and on the different sample sizes - therefore the results are not directly comparable. Nevertheless, according to the research, the highest share of bicycle traffic occurs in Poznan, and the lowest in Warszawa – despite the fact, that Warszawa has the highest rate of road length for bicycles per 100 km$^2$. The cities studied are therefore strongly differentiated in terms of bicycle traffic.

Table 1. Cycling infrastructure and share of bicycle traffic in the six largest Polish cities (based on ("GUS - Bank Danych Lokalnych," n.d.; Kostelecka & Pietrzak, 2015; Kostelecka et al., 2018; NBC, 2018; Olesków-Szlapka, Pawlyszyn, & Przybylska, 2020; VIA VISTULA, 2016; Wołkiewicz - marketing and social research, 2018))

| City | Number of inhabitants (2018) | Total length of roads for bicycles (2018) | | | Share of bicycle trips [%] (2015-2018) |
|---|---|---|---|---|---|
| | | [km] | [km/100km$^2$] | [km/10K inhabitants] | |
| Gdansk | 466 631 | 182.3 | 69.59 | 3.91 | 5.9 (2016) |
| Krakow | 771 069 | 213.7 | 65.38 | 2.77 | 6.9 (2018) |
| Lodz | 685 285 | 158.3 | 53.98 | 2.31 | no data |
| Poznan | 536 438 | 242.5 | 92.59 | **4.52** | **8.4** (2018) |
| Warszawa | **1 777 972** | **590.0** | **114.07** | 3.32 | 3.1 (2015) |
| Wroclaw | 640 648 | 260.0 | 88.79 | 4.06 | 6.0 (2018) |

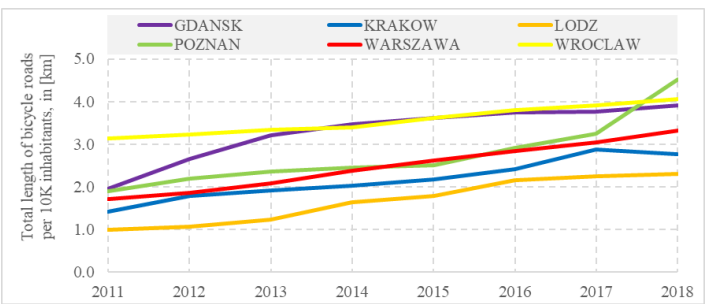
However, it is worth noting the very increase in the length of the network of roads for bicycles, which took place in all analyzed cities, in the years 2011-2018 (period of such data recording by GUS, ("GUS - Bank Danych Lokalnych," n.d.)). Figure 1 presents the variability of the length of the road network for bicycles in individual cities, in subsequent years. It has been concluded, that the best indicator is the length of the network for every 10K inhabitants, which allows for objective comparison of the scale of development of the bicycle network in the analyzed cities.

Statistically speaking, the biggest increase in the length of roads for bicycles per 10K inhabitants between 2011-2018 was in Gdansk and Poznan. On the other hand - invariably - the worst situation is in Lodz, despite more than doubling the total length of the network in the last 7 years. This indicator does not take into account the complexity and continuity of the bicycle network, which is also of great importance for the choice of the bicycle in everyday travels - however, it best reflects the relationship between the offered bicycle infrastructure and the number of potential users of the bicycle network.

The analysis of the number of traffic incidents involving cyclists and pedestrians in the largest Polish cities was carried out using the Police Accident and Collision Records System (SEWIK, (SEWiK, 2020)), in the period from 01.01.2007 to 31.12.2018. The database was made available by the Police for public use. The SEWIK database contains – among others - the following information on traffic incidents:

– general data of the traffic incident (incident ID, date, hour, number of participants),
– address of the incident (geographical coordinates, street name)
– location of the incident (e.g. sidewalk, road for bicycles, pedestrian crossing, bicycle crossing, roadway, junction, etc.),
– features of the infrastructure (street section or junction, traffic signals or no signalling, horizontal road marking or no road marking, speed limit at the place of incident),
– kind of incident (e.g. bike-running into a pedestrian, collision, overturning),
– light conditions (night, daylight, dusk, dawn),
– weather conditions (good conditions, cloudy, rainfall, snowfall, fog, blinding sun),
– data of all participants in the traffic incident: perpetrators and victims (age, sex, having a license to drive, driving experience),
– determining of the perpetrator of the incident and the type of penalty,
– consequences of accident (victims: death, serious injury, slight injury, no victim).

All recorded incidents were taken into account. Qualification and description of the incident, as well as an indication of the guilty parties (if possible) and determination of the scale of the victims' injuries were each time carried out by a police officer present at the scene of the incident - so the SEWIK database is based on official and verified information. This does not mean that the qualification in each case did not raise objections. Some descriptions of traffic incidents are not very precise, especially when the incident took place at the intersection of different elements of infrastructure, including the crossing of pedestrian and bicycle infrastructure. The doubts also concern some of the findings concerning the perpetrators of the incidents (especially accidents) - in such cases the issue was referred to the court and finally is listed in the database as unresolved guilt.




ig. 1. Comparison of the total length of bicycle paths in km per 10K inhabitants in the six largest Polish cities in 2011-2018 (own studies on the basis ("GUS - Bank Danych Lokalnych," n.d.))

It should also be mentioned that the database contains information only on those traffic incidents (including accidents) that were notified by one of the participants and required the intervention of a police officer. There is no reliable information on the number of incidents which, regardless of the consequences, were not notified.
All traffic incidents from SEWIK database were discussed to identify the causes and determine the perpetrators and victims. A group of statistical tools was used for this purpose, including a significance test for two independent proportions and Chi-squared test for trend in proportions. The calculations were performed using PQStat software (Więckowski, n.d.).

## 4. Research results

### 4.1. Number of traffic incidents, accidents and victims

A total of 1702 traffic incidents with the simultaneous participation of at least one pedestrian and at least one cyclist were analyzed. 964 of these incidents (56.6%) were accidents (with victims) - a total of 7 people died, 319 persons were seriously injured and another 708 people were slightly injured (Fig. 2).
If only those traffic incidents involving pedestrians and cyclists (without the participation of other vehicles) were to be distinguished - that is a total of 1637 incidents (96.2% of all incidents registered in SEWIK database).
More interesting, however, is the rate of increase in the number of traffic incidents. In years: In 2007 and 2008 there were only 65 incidents each, and in 2010 there were still only 72. A significant breakthrough occurred in 2011, when 125 such incidents took place. In 2014 there were already 200 incidents, but over the next few years their number ranged from 162-193 to exceed the barrier of 200 cases in 2018 - then there were 213 incidents. Figure 3 shows the variability of the number of traffic incidents involving both pedestrians and cyclists (without the participation of other traffic participants) in individual cities together with the average number of incidents in the group of all six analyzed cities.
Looking only at the absolute numbers of such incidents in 2018, one can see that they are not significant. However, the increase in the number of incidents is worrying - especially in the context of the expected increase in bicycle traffic. It is no coincidence, that in the cities where the greatest increase in the total length of the bicycle network, calculated in km per 10K inhabitants (Gdansk and Poznan), the smallest increase in the number of traffic incidents between cyclists and pedestrians was observed.
Much more important than the number of traffic incidents is the number of accident victims and the consequences of accidents. The SEWIK database makes it possible to determine the division of victims into fatalities, seriously injured and slightly injured people. In all 938 accidents involving only pedestrians and cyclists, 5 people were killed, and 989 people were injured. The number of fatalities – in statistical terms – is relatively small. It is 5 fatalities in 12 years, evenly distributed in subsequent years (maximum one victim per year). This is 0.5% of all victims of such accidents (Fig 4).

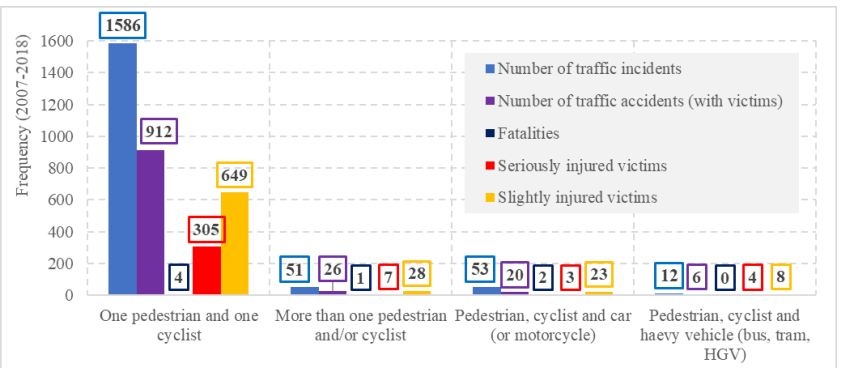



Fig. 2. Overview of the number of traffic incidents and the number of victims in traffic accidents involving at least one pedestrian and at least one cyclist - in the six largest Polish cities in 2007-2018 (own studies on basis (SEWiK, 2020))

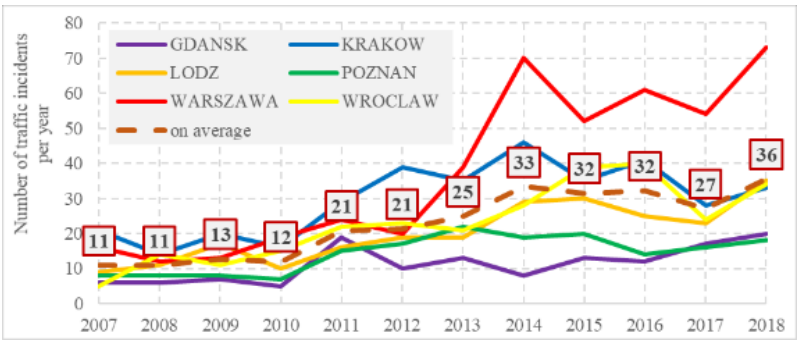



Fig. 3. Overview of the number of traffic incidents involving at least one pedestrian and at least one cyclist (and no other vehicles) in the six largest Polish cities in 2007-2018 (own studies on basis (SEWiK, 2020))

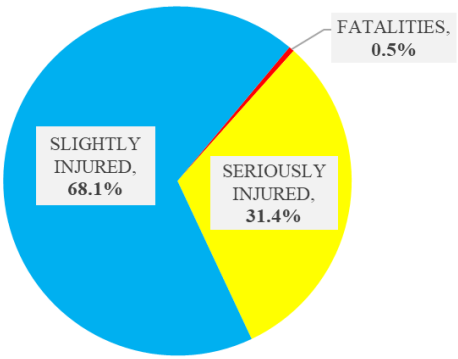
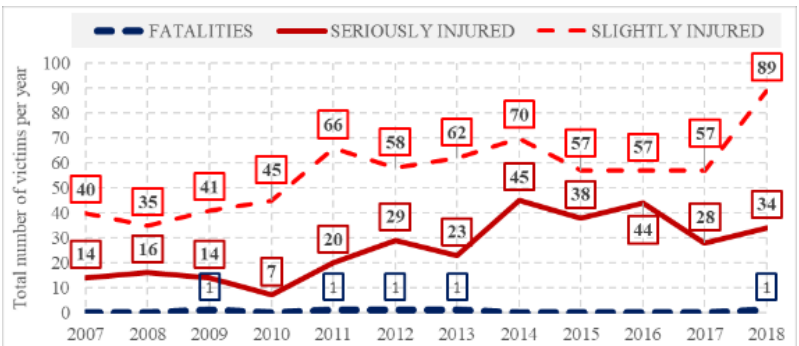



Fig. 4. The share of fatalities and injuries in accidents involving at least one pedestrian and at least one cyclist (and no other vehicles) in the six largest Polish cities in 2007-2018 (own studies on basis (SEWiK, 2020))

However, it should be borne in mind that these people died in accidents between the weakest, unprotected road users. The number of seriously injured people is already much higher, that is a total of 312 people (31.4%), whereas at least theoretically should not result in severe injuries, because they take place at relatively low speeds and the impact force is disproportionately lower than in accidents of pedestrians and cyclists with cars. In turn, a total of 677 people were slightly injured.

It is worrying that both the number of seriously and slightly injured people in accidents between cyclists and pedestrians is gradually increasing – throughout the whole analyzed period 2007-2018 it is an increase by – respectively: 140% and 123%. In this period, the least number of victims was in 2008 (51 injured) and the most in 2018, when one person was killed and 123 people were injured (Fig. 5).




ig. 5. Overview of the number of victims in accidents involving at least one pedestrian and at least one cyclist (and no other vehicles) in the six largest Polish cities in 2007-2018 (own studies on the basis (SEWiK, 2020))

However, the proportion of people killed and seriously injured to the number of all victims seems too high, which indicates the need to make a good diagnosis of the causes of such incidents (especially accidents) and to take action to reduce the consequences of accidents between cyclists and pedestrians. Although it must be added at this point, that the number of traffic incidents between pedestrians and cyclists that go unreported and do not appear in police statistics (SEWIK database) is unknown.

### 4.2. Circumstances of traffic incidents (including accidents)

The majority of traffic incidents between cyclists and pedestrians are the cases when a bike is running into a pedestrian. This was the case in as many as 1517 cases, which accounts for 93% of all analyzed incidents from 2007-2018. Only once this share fell below 90% - in 2017 it was 89% of cases. The remaining kinds of traffic incidents have very low repeatability, only cases of a cyclist overturning can be distinguished - in 12 years there were 37 of them in total, which is only 2% of all incidents. This disproportion is shown in Figure 6, where it can also be seen, that in the period 2007-2011 the vast majority of traffic incidents were the accidents (incidents with victims), while in subsequent years of analysis, despite an increase in the number of incidents, the number of accidents remained at a level rarely exceeding 100 cases per year.

The circumstances of traffic incidents between cyclists and pedestrians (bike-running into a pedestrian and other cases) can vary, among other things, in terms of the type of infrastructure used and the light or weather conditions. Figure 7 shows the impact of the type of infrastructure and light/weather conditions on the number of incidents in subsequent years of the analysis, depending on the purpose of the infrastructure and the occurrence of junctions, traffic signals and horizontal road marking. The charts also show the variability of the number of accidents with victims (killed and injured).

In the whole analyzed period 2007-2018, a greater number of traffic incidents between pedestrians and cyclists took place outside of the junctions than at the junction areas. Initially, it was about twice as many incidents, starting from 2011 one can see a particularly large increase in group of incidents outside the junctions. Similar observations can be made in the case of the part of incidents, that ended with injuries to participants. This is probably due to the development of bicycle infrastructure in the analyzed cities. The same is true in the case of traffic signals - since 2011 it is when they do not exist (or do not work) that much more incidents are observed. However, in the case of horizontal road marking (by line or surface color), the behavior is different - much more incidents (including accidents) between cyclists and pedestrians took place when road marking existed.

Cases of bike-running on pedestrians (and also other types of incidents) occurred on elements of infrastructure dedicated to pedestrians (sidewalks and pedestrian crossings) and on elements of infrastructure designed for cyclists (bicycle roads and lanes, locks, bicycle crossings). Traffic incidents also took place on elements of the remaining infrastructure, including places where pedestrian and bicycle traffic is carried out in general traffic.

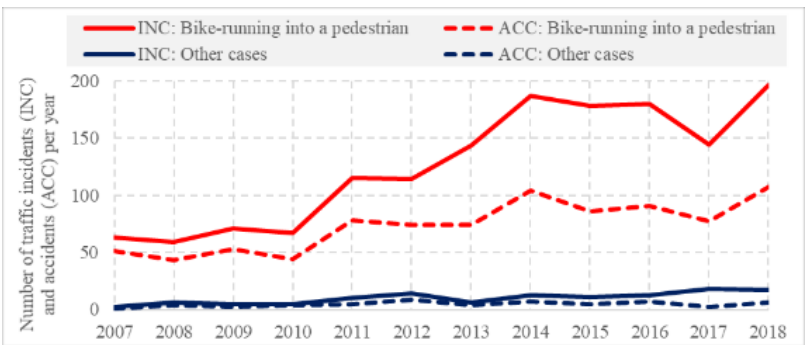



Fig. 6. Differentiation of the numbers of traffic incidents (including accidents) between cyclists and pedestrians with division into two kinds of incidents: bike-running into a pedestrian and other cases in the six largest Polish cities in 2007-2018 (own studies on basis (SEWiK, 2020))

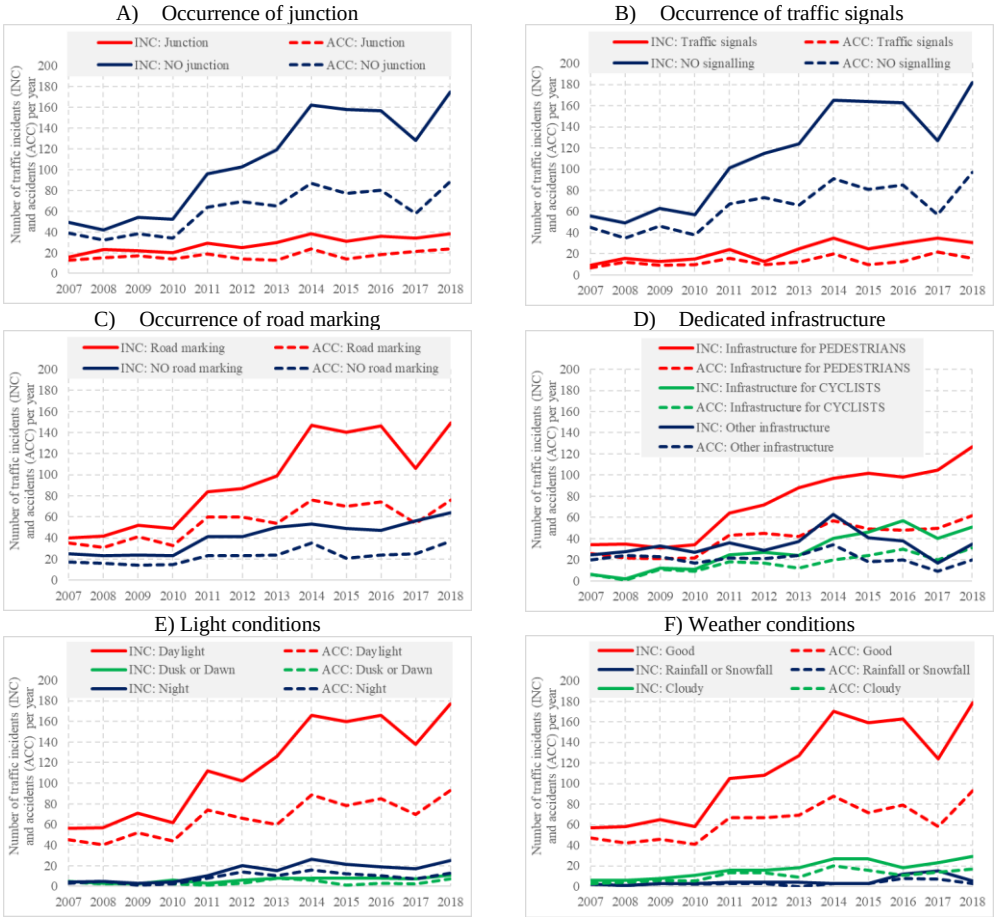



Fig. 7. Differentiation of traffic incidents between cyclists and pedestrians in terms of the type of infrastructure and also light and weather conditions in the six largest Polish cities in 2007-2018 (own studies on the basis (SEWiK, 2020))

In all three cases, an increase in the number of incidents can be observed, but it is particularly large in ıe case of pedestrian infrastructure. This is a very ·orrying phenomenon, because it shows that the in·ease in bicycle traffic results in a decrease in safety ı places where safety of pedestrians should be guarıteed in the first place. However, more far-reaching ɔnclusions will be presented after the analysis of ıe participation of perpetrators and victims in roups of pedestrians and cyclists (next subsection). he circumstances of traffic incidents between cy·ists and pedestrians can vary also on the light conitions and atmospheric conditions. The vast majory of traffic incidents, as much as 85% occurred in daylight and 84% in good weather conditions. The same is true in case of accidents, with 85% and 82% of all recorded accidents, respectively. These results are not surprising - most bicycle journeys (as well as most pedestrian journeys) take place in daylight, so the probability of road incidents is the highest. Weather conditions also affect the volume of bicycle traffic, so it is not surprising, that such a significant share of incidents (accidents) takes place in good weather conditions. However, these results clearly show that much more important than light and weather conditions are the behaviors of traffic participants.

### 4.3. Shares of perpetrators of traffic incidents

Of all analyzed traffic incidents between pedestrians and cyclists in 2007-2018 - in as many as 1142 cases, the perpetrators were cyclists, which is 69.8% of all incidents (Fig. 8).

Pedestrians were responsible for a further 477 incidents (29.1%), while in only 5 cases both pedestrian and cyclist were found guilty. On the other hand, in 13 cases, a police officer was not able to identify the perpetrator. A general analysis of the share of perpetrators leaves no doubt as to which group is more responsible for this type of incident, although as can be seen in Figure 8, the structure of perpetrators changes over time and the share of perpetrators in the pedestrian group increases.

However, the information will be incomplete without taking into account the diversity of the traffic incidents locations, including the type of infrastructure, as well as lighting and weather conditions. Table 2 compares the shares of the perpetrators of the incidents depending on the occurrence of the junction, traffic signals, horizontal road marking, purpose of the dedicated infrastructure (for pedestrians, for cyclists and for other users), lighting and weather conditions - i.e. in accordance with the division applied earlier, on figure 7.

The above statements show that, compared to the overall share of perpetrators of all incidents, the cyclists are more likely to create incidents within junction areas than outside junctions and in places, where there are traffic signals and - which may come as a surprise - in good lighting and weather conditions. Pedestrians, on the other hand, are more likely to cause incidents when there is horizontal road marking, as well as under worse lighting and weather conditions. Cyclists are also the perpetrators of the vast majority of incidents on elements of infrastructure dedicated to pedestrians (94.4%), while pedestrians are the perpetrators of the majority of incidents on bicycle infrastructure (72.7%). Such a division of perpetrators may not be surprising, pedestrians have priority on infrastructure elements dedicated to them (usually the sidewalk), if they are then perpetrators of incidents with cyclists - this is usually the result of very unusual behavior. However, on elements of cycling infrastructure the matter is not so obvious - incidents occur, for example, at crossings of bicycle paths - then the fault may be on both sides and is often difficult to determine. On the other hand, on the remaining infrastructure, the perpetrators' shares in both groups are the closest (cyclists: 53%, pedestrians 46%). Due to the low number of incidents with or without an established perpetrator, statistical tests enabling comparison of individual shares were abandoned.

Such comparisons were made in the case of traffic incidents where the perpetrators were either cyclists or pedestrians. For the results thus extracted, the significance tests for two proportions were performed. This test is used to verify the null hypothesis informing that the distinguished proportions from two independent populations which the samples were drawn, are equal. Table 3 lists the perpetrators'

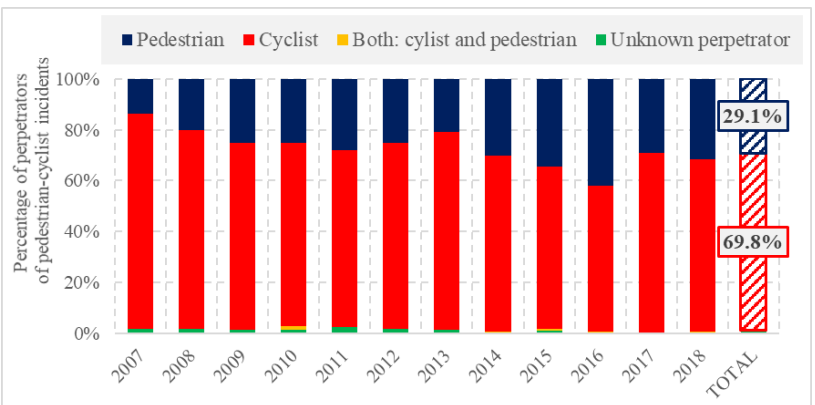



Fig. 8. Shares of perpetrators of traffic incidents between pedestrians and cyclists in the six largest Polish cities in 2007-2018 (own studies on the basis (SEWiK, 2020))

shares in a limited number of incidents (1619), together with the results of the significance tests conducted for two independent proportions (Więckowska, n.d.). In all mentioned cases, the null hypothesis was rejected at the 0.05 significance level.

As it can be seen, statistically significant differences were obtained in the case of the influence of the presence of a junction, traffic signals and horizontal road marking on the occurrence of traffic incidents. However, the influence of light and atmospheric conditions turned out to be statistically insignificant (at the significance level of 0.05).

In the case of the type of infrastructure in terms of its purpose for particular groups of traffic participants (dedicated for pedestrians, dedicated for cyclists and other infrastructure), significance tests have been abandoned, as the differences between the shares of perpetrators are so large, that they do not require such confirmation. Only a graphical comparison of the shares of perpetrators in groups of pedestrians and cyclists was presented for individual aggregated types of infrastructure (Fig. 9).

These results shown in Table 3 and Figure 9 do not differ much from those presented in Table 2. Percentages of perpetrators in groups of pedestrians and cyclists increased slightly (by 1.1% maximum). This is due to the relatively low number of incidents in which no perpetrator was identified or pedestrians and bicyclists were both perpetrators.

Table 2. Shares of perpetrators of traffic incidents involving at least one pedestrian and at least one cyclist (and no other vehicles) in terms of the type of infrastructure and light/weather conditions in the six largest Polish cities in 2007-2018 (own studies on the basis (SEWiK, 2020))

| **Circumstances of traffic incidents** | **Share of a group of traffic participants as perpetrators of incidents [-]** | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **Lack** | **Pedestrians** | **Cyclists** | **Both** | **Lack** | **Pedestrians** | **Cyclists** | **Both** |
| Occurrence of junction | Junction (n=342) | | | | NO junction (n=1295) | | | |
| | 0.012 | 0.225 | **0.760** | 0.003 | 0.007 | 0.309 | **0.681** | 0.003 |
| Occurrence of traffic signals | Traffic signals (n=271) | | | | NO traffic signals (n=1366) | | | |
| | 0.000 | 0.199 | **0.797** | 0.004 | 0.010 | 0.310 | **0.678** | 0.003 |
| Occurrence of road marking | Horizontal road marking (n=1141) | | | | NO horizontal road marking (n=496) | | | |
| | 0.007 | 0.323 | **0.666** | 0.004 | 0.010 | 0.218 | **0.770** | 0.002 |
| Light conditions | Daylight (n=1393) | | | | Other conditions (n=244) | | | |
| | 0.009 | 0.286 | **0.701** | 0.004 | 0.000 | 0.324 | **0.676** | 0.000 |
| Weather conditions | Good conditions (n=1373) | | | | Other conditions (n=264) | | | |
| | 0.009 | 0.285 | **0.704** | 0.002 | 0.004 | 0.326 | **0.663** | 0.008 |
| Dedicated infrastructure | Infrastructure for pedestrians (n=887) | | | | Infrastructure for cyclists (n=341) | | | |
| | 0.008 | 0.046 | **0.944** | 0.002 | 0.012 | **0.727** | 0.258 | 0.003 |
| | Other infrastructure (n=409) | | | | | | | |
| | 0.005 | 0.460 | **0.531** | 0.005 | | | | |

Table 3. Shares of perpetrators of traffic incidents involving at least one pedestrian and at least one cyclist (and no other vehicles) in the six largest Polish cities in 2007-2018, only incidents where the only perpetrators were pedestrians or cyclists (own studies on the basis (SEWiK, 2020))

| **Circumstances of traffic incidents** | **Share of a group of traffic participants as perpetrators of incidents [-]** | | | | **Statistical significance of differences** |
|---|---|---|---|---|---|
| | **Pedestrians** | **Cyclists** | **Pedestrians** | **Cyclists** | |
| Occurrence of junction | Junction (n=337) | | NO junction (n=1282) | | **YES** |
| | 0.228 | **0.772** | 0.312 | **0.688** | |
| Occurrence of traffic signals | Traffic signals (n=270) | | NO traffic signals (n=1349) | | **YES** |
| | 0.200 | **0.800** | 0.314 | **0.686** | |
| Occurrence of road marking | Road marking (n=1129) | | NO road marking (n=490) | | **YES** |
| | 0.327 | **0.673** | 0.220 | **0.780** | |
| Light conditions | Daylight (n=1375) | | Other conditions (n=244) | | NO |
| | 0.289 | **0.711** | 0.324 | **0.676** | |
| Weather conditions | Good conditions (n=1358) | | Other conditions (n=261) | | NO |
| | 0.288 | **0.712** | 0.330 | **0.670** | |

### 4.4. Shares of victims of traffic incidents

A similar analysis as in the case of perpetrators of traffic incidents between pedestrians and cyclists was also carried out for victims of incidents that resulted in victims (killed and seriously or slightly injured), i.e. accidents. Undoubtedly, the fact that 42.7% of the incidents in 2007-2018 did not result in victims is very positive (Fig. 10). However, again, it is important to remember that not all incidents between pedestrians and bicyclists are reported and appear in the SEWIK database. One can only presume that mostly victimless incidents are not reported, although this may not always be the case.

Starting in 2007, there was a successive increase in the share of victimless traffic incidents, until 2015, when a record 51.9% of such incidents were reached. However, in the following years, this growth slowed down and then began to decrease slightly to 46.9% in 2018 (end of the analysis period).

In total, more than half of the incidents (57.3%) in 2007-2018 ended up injured at least one of the traffic participants: in 736 cases there were pedestrians (45.0% of the incidents), in 155 cases – cyclists(9.5%), and in 47 incidents (2.9%) - both, pedestrians and cyclists. Similar to the perpetrators, different proportions of pedestrians and cyclists were observed in the case of victims (Table 4).

More incidents without victims took place outside junction areas (43.5%) than within such areas. It was similar in the case of lack of horizontal road marking (44.8%). Good light and weather conditions also resulted in fewer victimless incidents – respectively:

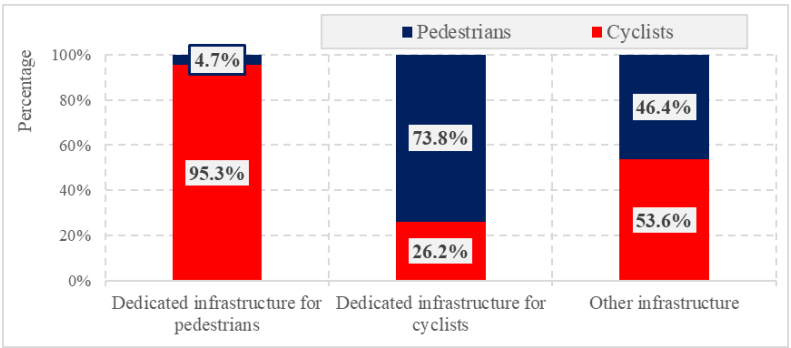



Fig. 9. Difference of the shares in perpetrators of traffic incidents between cyclists and pedestrians in terms of the purpose of infrastructure, in the six largest Polish cities in 2007-2018, only accidents where the only perpetrators were pedestrians or cyclists (own studies on the basis (SEWiK, 2020))

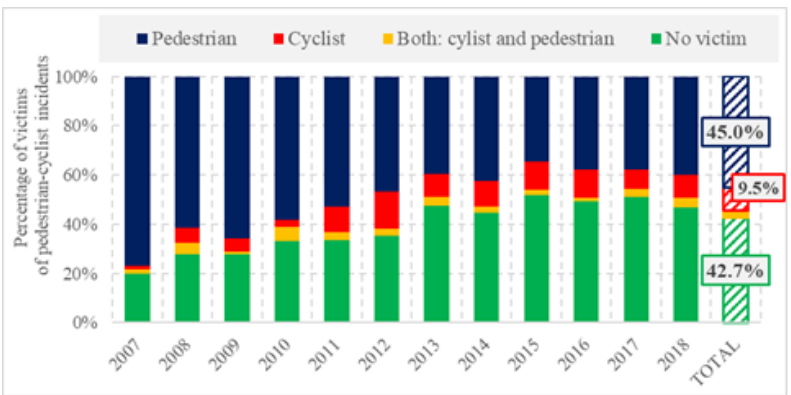



Fig. 10. Shares of victims of traffic incidents between pedestrians and cyclists in the six largest Polish cities in 2007-2018 (own studies on the basis (SEWiK, 2020))

42.9% and even 44.0%. Besides, a higher percentage of incidents without victims concerned pedestrian infrastructure (45.1%) than bicycle infrastructure (41.6%) and remaining infrastructure (only 38.4%). The relatively high share of traffic incidents without injuries is very encouraging information, but it somewhat disturbs the view of the effects of incidents in groups of pedestrians and cyclists. Therefore, to find out the structure of pedestrians and cyclists in incidents with victims, in the further analysis only those accidents in which either pedestrians or cyclists suffered were compared (Table 5). The traffic accidents suffered by both pedestrians and cyclists were omitted here, but there were relatively few of them - less than 3% of cases.

The results of this comparison are very unfavorable for the pedestrian group. They were victims of as many as 82.6% of the accidents so selected. A particularly high proportion of pedestrians as victims was observed in the case of accidents occurring at junctions and in the areas of traffic signals operation, and in the absence of horizontal road marking - in each of these cases the percentage of pedestrians in victims was greater than 87%. Good light conditions (daylight) were also not an ally of pedestrians, while weather conditions were neutral for the structure of victims. However, the tests for two independent proportions confirmed the statistical significance of the differences (at the significance level of 0.05) only in case of occurrence of the junction and horizontal road marking.

Table 4. Shares of victims of traffic incidents involving at least one pedestrian and at least one cyclist (and no other vehicles) in the six largest Polish cities in 2007-2018 (own studies on the basis (SEWiK, 2020))

| **Circumstances of traffic incidents** | **Share of a group of traffic participants as victims of incidents [-]** | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **Lack** | **Pedestrians** | **Cyclists** | **Both** | **Lack** | **Pedestrians** | **Cyclists** | **Both** |
| Occurrence of junction | Junction (n=342) | | | | NO junction (n=1295) | | | |
| | 0.398 | **0.500** | 0.064 | 0.038 | 0.435 | **0.436** | 0.103 | 0.026 |
| Occurrence of traffic signals | Traffic signals (n=271) | | | | NO traffic signals (1366) | | | |
| | 0.421 | **0.469** | 0.066 | 0.044 | 0.428 | **0.446** | 0.100 | 0.026 |
| Occurrence of road marking | Road marking (n=1141) | | | | NO road marking (n=496) | | | |
| | 0.418 | **0.442** | 0.112 | 0.028 | 0.448 | **0.468** | 0.054 | 0.030 |
| Light conditions | Daylight (n=1393) | | | | Other conditions (n=244) | | | |
| | 0.429 | **0.452** | 0.090 | 0.029 | 0.418 | **0.434** | 0.123 | 0.025 |
| Weather conditions | Good conditions (n=1373) | | | | Other conditions (n=264) | | | |
| | **0.440** | 0.436 | 0.093 | 0.031 | 0.360 | **0.519** | 0.102 | 0.019 |
| Dedicated infrastructure | Infrastructure for pedestrians (n=887) | | | | Infrastructure for cyclists (n=341) | | | |
| | 0.451 | **0.483** | 0.043 | 0.024 | **0.416** | 0.346 | 0.208 | 0.029 |
| | Other infrastructure (n=409) | | | | | | | |
| | 0.384 | **0.465** | 0.112 | 0.039 | | | | |

Table 5. Shares of victims of traffic incidents involving at least one pedestrian and at least one cyclist (and no other vehicles) in the six largest Polish cities in 2007-2018, only incidents where the only victims were pedestrians or cyclists (own studies on the basis (SEWiK, 2020))

| **Circumstances of traffic incidents** | **Share of a group of traffic participants as victims of incidents [-]** | | | | **Statistical significance of differences** |
|---|---|---|---|---|---|
| | **Pedestrians** | **Cyclists** | **Pedestrians** | **Cyclists** | |
| Occurrence of junction | Junction (n=193) | | NO junction (n=698) | | **YES** |
| | **0.886** | 0.114 | **0.809** | 0.191 | |
| Occurrence of traffic signals | Traffic signals (n=145) | | NO traffic signals (n=746) | | NO |
| | **0.876** | 0.124 | **0.816** | 0.184 | |
| Occurrence of road marking | Road marking (n=632) | | NO road marking (n=259) | | **YES** |
| | **0.797** | 0.203 | **0.896** | 0.104 | |
| Light conditions | Daylight (n=755) | | Other conditions (n=136) | | NO |
| | **0.834** | 0.166 | **0.779** | 0.221 | |
| Weather conditions | Good conditions (n=727) | | Other conditions (n=164) | | NO |
| | **0.824** | 0.176 | **0.835** | 0.165 | |

The results of the analysis of the impact of the infrastructure designation for particular user groups on the victim structure among cyclists and pedestrians clearly show, that pedestrians are always at a disadvantage in this respect. This is the case both for elements of the infrastructure designed for cyclists (62.4%) and for other infrastructure (80.5%). In the case of infrastructure dedicated to pedestrians, they constitute as much as 91.8% of the victims (Fig. 11). Since the individual shares differ by several percent each, the significance tests for proportions were abandoned - the results were a foregone conclusion. The presented results of the participation of victims in groups of pedestrians and cyclists confirmed that it is not legitimate to put equality between these two groups of vulnerable infrastructure users. Pedestrians are much more vulnerable and should be protected to a greater extent, not only from car traffic but also from bicycle traffic - especially within the infrastructure dedicated for them, but also at junctions, where participation of pedestrians in victims is also above the average.

At this point it can be considered that the first of the research hypotheses has been proved - the type of infrastructure has at least a partial impact on the structure of perpetrators and victims of incidents between pedestrians and cyclists.

### 4.5. Changes in shares of perpetrators and victims of traffic incidents in the period 2007-2018

The increase in cycling is a strong fact, as is the increase in the number of traffic incidents between pedestrians and cyclists - as shown in chapters 4.1 and 4.2. It is also a fact, that more such incidents are caused by cyclists, while most victims are pedestrians - what was presented in chapters 4.3 and 4.4.

However, in addition to knowing the structure of perpetrators and victims, it is also necessary to know the dynamics of changes in these structures. A more complete picture of traffic incidents will make it easier to find more effective tools for protection for both groups of traffic participants. It will enable to define the rules of mutual coexistence at the meeting points of pedestrian and bicycle infrastructure, as well as in the separated spaces, dedicated to pedestrians or cyclists, like sidewalks and roads for bicycles.

The analysis of the changes in shares of perpetrators of traffic incidents and victims of accidents between pedestrians and cyclists was carried out taking into account the previously applied divisions of accident types in terms of the presence (or not) of junctions, traffic signals, horizontal road markings, purpose of infrastructure (for pedestrian, for cyclist and other infrastructure) and also lighting and weather conditions. In all analyzed cases, the shares of perpetrators and victims were compared in particular years of the analysis, in the period 2007-2018. Figures 12-14 present a selected graphical set of shares of perpetrators of incidents on the background of the numbers of all analyzed incidents, depending on the presence of junctions and horizontal road markings, as well as the purpose of infrastructure. Figures 15-17 show similar statements for the shares of victims of accidents between pedestrians and cyclists.

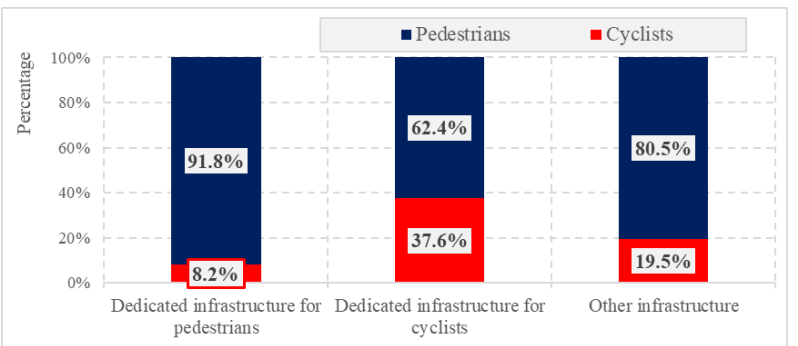
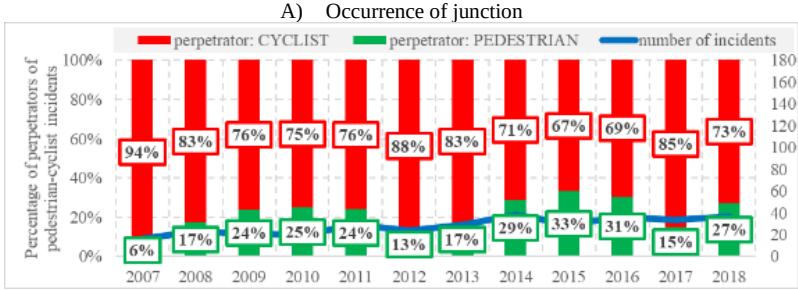



Fig. 11. Difference of the shares in victims of traffic accidents between cyclists and pedestrians in terms of the purpose of infrastructure, in the six largest Polish cities in 2007-2018, only accidents where the only victims were pedestrians or cyclists (own studies on the basis (SEWiK, 2020))

A) Occurrence of junction




B) NO junction

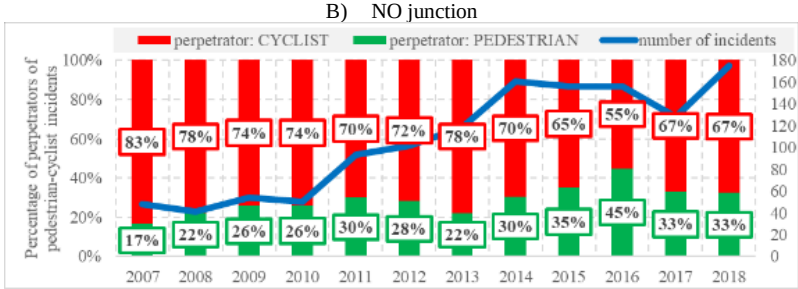
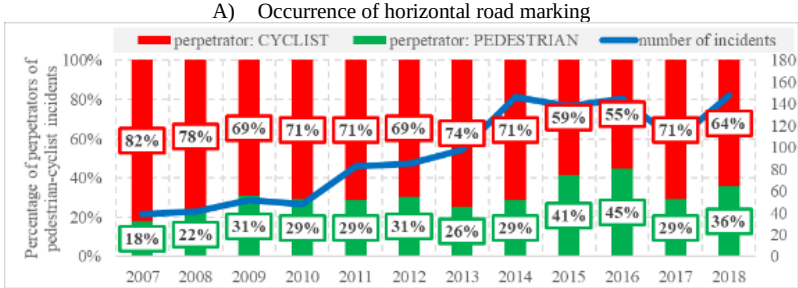
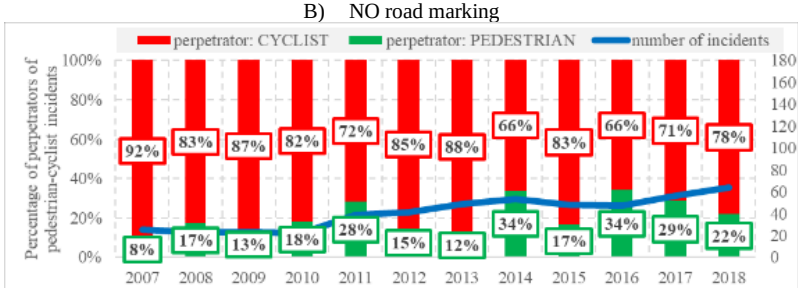



Fig. 12. Differences of the shares in perpetrators of traffic incidents between cyclists and pedestrians depending on the occurrence of junction, in the six largest Polish cities in 2007-2018, only incidents where the only perpetrators were pedestrians or cyclists (own studies on the basis (SEWiK, 2020))

A) Occurrence of horizontal road marking




B) NO road marking




ig. 13. Differences of the shares in perpetrators of traffic incidents between cyclists and pedestrians depending on the occurrence of horizontal road marking, in the six largest Polish cities in 2007-2018, only incidents where the only perpetrators were pedestrians or cyclists (own studies on the basis (SEWiK, 2020))

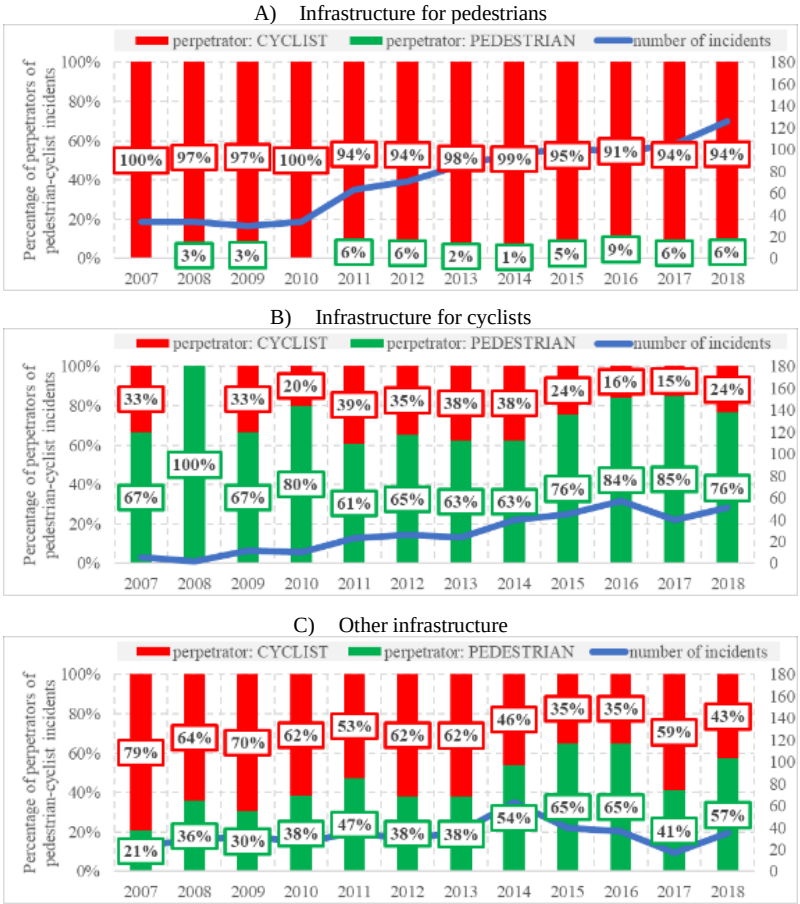



Fig. 14. Differences of the shares in perpetrators of traffic incidents between cyclists and pedestrians depending on the purpose of the infrastructure, in the six largest Polish cities in 2007-2018, only incidents where the only perpetrators were pedestrians or cyclists (own studies on the basis (SEWiK, 2020))

Evaluation of the obtained results is difficult due to the large disproportion of the numbers of traffic incidents between different elements of infrastructure and in different external conditions. It is particularly difficult to assess the trend in the case of incidents within intersections and on other infrastructure elements (not dedicated to pedestrians and cyclists). In these cases, the assessment is very superficial and although some trends are visible, the interpretation must be treated with caution.

In the case of incidents outside of junctions, a gradual increase in the share of pedestrians as perpetrators is evident throughout the analysis period (2007-2018), but the trend seems to be reversing in the last two years. Whether this is a sustainable process will prove to be the case in the years to come, when the bicycle traffic will still increase. On the other hand, the increasing share of perpetrators in the pedestrian group is more visible in bicycle infrastructure, while in the case of pedestrian infrastructure, the upward trend has stopped permanently.

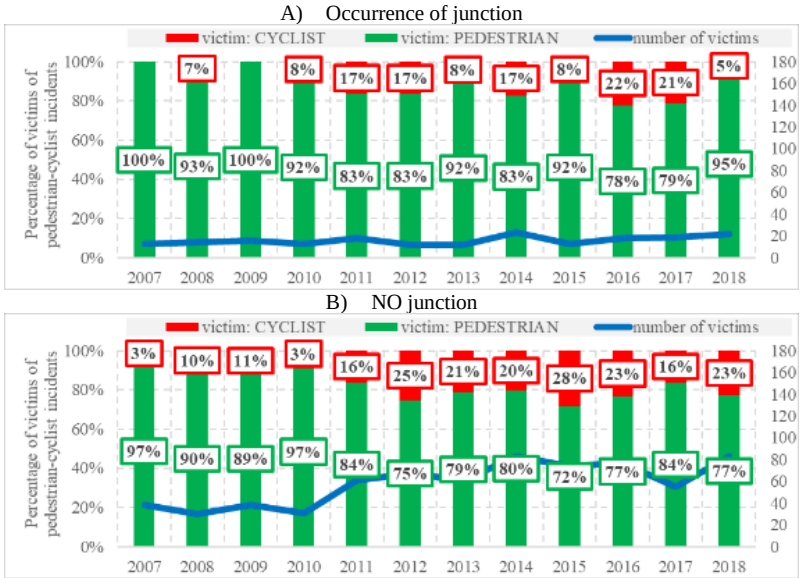
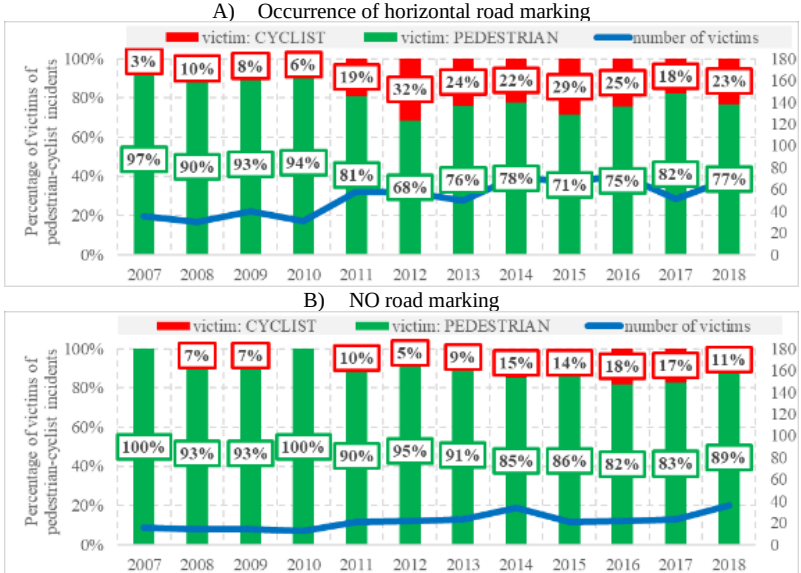



Fig. 15. Differences of the shares in victims of traffic incidents between cyclists and pedestrians depending on the occurrence of junction, in the six largest Polish cities in 2007-2018, only accidents where the only victims were pedestrians or cyclists (own studies on the basis (SEWiK, 2020))




ig. 16. Differences of the shares in victims of traffic incidents between cyclists and pedestrians depending on the occurrence of horizontal road marking, in the six largest Polish cities in 2007-2018, only accidents where the only victims were pedestrians or cyclists (own studies on the basis (SEWiK, 2020))

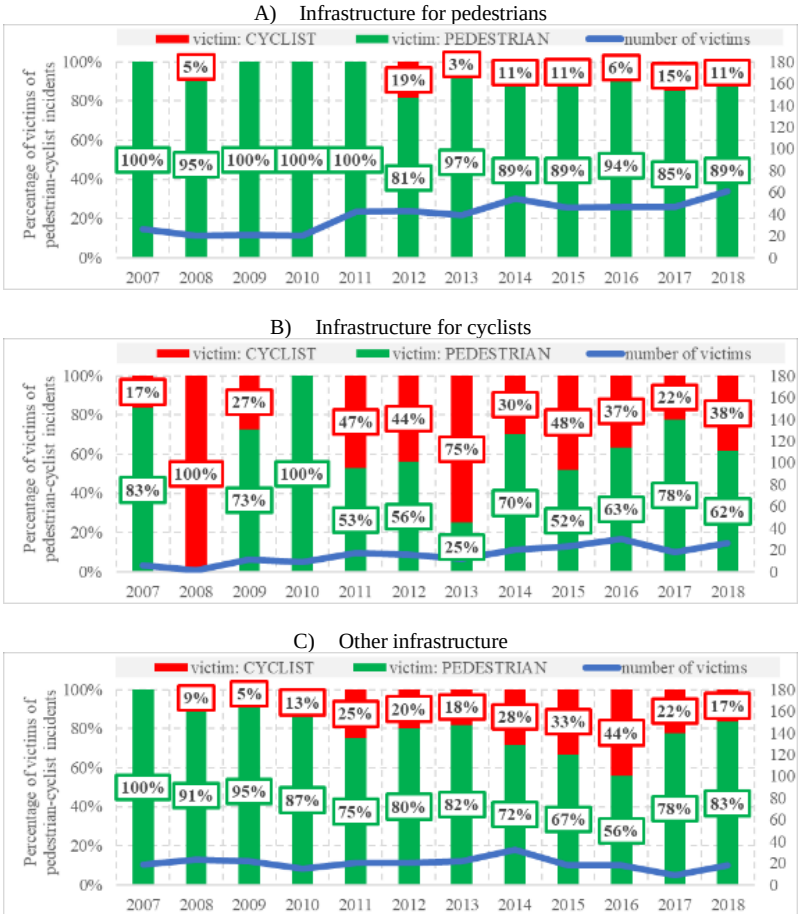



Fig. 17. Differences of the shares in victims of traffic incidents between cyclists and pedestrians depending on the purpose of the infrastructure, in the six largest Polish cities in 2007-2018, only incidents where the only victims were pedestrians or cyclists (own studies on the basis (SEWiK, 2020))

In the case of victims, the trend of decreasing share of victims among the pedestrians has been levelling out, but with a slight increase in recent years. Also in this case, the key will be the upcoming years, in which an increase in bicycle traffic and thus equalization of the proportion of bicycle and pedestrian traffic is expected.

However, based on the results obtained, it can be finally concluded that the share of pedestrians as perpetrators of traffic incidents is gradually increasing, although it is still incomparable to that of cyclists. Larger interpretation problems concern victims of accidents between pedestrians and cyclists. The share of pedestrians in the victims had a decreasing tendency, but in recent years the share of victims on the side of pedestrian traffic participants has increased again. More complete information was provided by the stratification of the sample, especially on the types of infrastructure used.

In order to check, if there are trends in the shares of perpetrators (and victims) in groups of pedestrians and cyclists in traffic incidents between these groups of traffic participants, in the period 2007-2018, the Chi-squared test for trend was performed. This test is used to determine whether there is a trend in pro-

portion for particular categories of analyzed variables. The null hypothesis that in the analyzed population the trend in a proportion of perpetrators (victims) in 2007-2018 does not exist was examined. The application of the Chi-squared test should be preceded by a check of Cochran's condition, which states that none of the expected frequencies should be smaller than one and additionally, no more than 20% of frequencies should be lower than five. If the Cochran condition is not fulfilled, the results of the Chi-square test are not trustworthy and can only be used as illustrative. The results of the checked Cochran's condition and conducted Chi-squared test for all mentioned cases are presented in Table 6.

In the vast majority of cases, the results of the Chi-square test indicate the presence of trends in the following years in the participation of groups of pedestrians and cyclists as perpetrators and victims of traffic incidents between these two groups of traffic participants. In the case of the perpetrators of the traffic incidents, a trend could not be found only for the incidents within the junction areas and within the traffic light operation areas - and these are often (though not always) the same places: signalized junctions. On the other hand, in the case of accident victims, the trend could not be statistically proved in the case of incidents in the area of junctions (but in the area of the operating traffic signals), on the dedicated bicycle infrastructure, as well as in the case of traffic incidents occurring under light conditions other than daylight and weather conditions other than good. However, in cases where the Cochran condition has not been fulfilled, conclusions are not strong.

## 5. Conclusions

There is no denying that although both pedestrians and cyclists together constitute a group of unprotected traffic participants - this group is not homogenous. In incidents, where there are direct conflicts between the two types of traffic participants, the cyclist has the advantage in most cases. The cyclist usually moves faster than the pedestrian and has a stronger temptation to show his advantage. This is evident in the showed statistics - cyclists are still responsible for a much higher number of incidents with pedestrians (including accidents), but mainly pedestrians suffer their health consequences.

Table 6. The Chi-squared test results for trends of the shares of perpetrators and victims in groups of pedestrians and cyclists in traffic incidents between cyclists and pedestrians in terms of the type of infrastructure, light and weather conditions, in the six largest Polish cities – only incidents, where the only victim was a pedestrian or cyclist (on the basis (SEWiK, 2020))

| Circumstances of traffic incidents | | Significance of trend | | | | | |
|---|---|---|---|---|---|---|---|
| | | Perpetrators | | | Victims | | |
| | | Cochran's condition | Chi² test statistic | Chi² test result | Cochran's condition | Chi² test statistic | Chi² test result |
| Occurrence of junction | Junction | **fulfilled** | 1.91 | - | not fulfilled | 2.44 | - |
| | NO junction | **fulfilled** | 12.58 | **TREND** | **fulfilled** | 11.39 | **TREND** |
| Occurrence of traffic signals | Traffic signals | not fulfilled | 1.85 | - | not fulfilled | 11.03 | **TREND** |
| | NO traffic signals | **fulfilled** | 13.84 | **TREND** | **fulfilled** | 7.87 | **TREND** |
| Occurrence of road marking | Road marking | **fulfilled** | 9.98 | **TREND** | **fulfilled** | 10.65 | **TREND** |
| | NO road marking | **fulfilled** | 5.09 | **TREND** | not fulfilled | 4.67 | **TREND** |
| Dedicated infrastructure | Infrastructure for pedestrians | not fulfilled | 4.48 | **TREND** | not fulfilled | 7.95 | **TREND** |
| | Infrastructure for cyclists | not fulfilled | 4.99 | **TREND** | not fulfilled | 0.14 | - |
| | Other infrastructure | **fulfilled** | 17.93 | **TREND** | not fulfilled | 11.40 | **TREND** |
| Light conditions | Daylight | **fulfilled** | 9.46 | **TREND** | **fulfilled** | 10.88 | **TREND** |
| | Other conditions | not fulfilled | 8.85 | **TREND** | not fulfilled | 3.50 | - |
| Weather conditions | Good conditions | **fulfilled** | 10.44 | **TREND** | **fulfilled** | 20.76 | **TREND** |
| | Other conditions | not fulfilled | 6.23 | **TREND** | not fulfilled | 0.81 | - |

The paper proves that the type of infrastructure and light/weather conditions influences the structure of perpetrators (and victims) of incidents (and accidents) between cyclists and pedestrians. The results confirm that the proportion of accidents caused by pedestrians is increasing, but they still cause fewer such accidents than cyclists. In contrast, the proportion of pedestrian casualties in such accidents has been steadily decreasing. Thus, it can be said that the results of the statistical analyses performed confirm the hypotheses formulated in Chapter 2.

The results of the conducted analyses indicate an urgent need to introduce remedial actions aimed at working out good conditions of mutual coexistence of pedestrians and cyclists in a common space. Further development of cycling should not take place at the expense of worsening pedestrian traffic conditions. There is a need to review existing engineering solutions in terms of mutual adaptation of pedestrian and bicycle infrastructure. It should be taken into account, that it is not only about the safety of pedestrians and cyclists, but also about their comfort of using the infrastructure intended for them.

The research will be continued to include additional data from the next following years and a more detailed view on the influence of individual infrastructure elements on traffic incidents between cyclists and pedestrians.

**Acknowledgement**

The article has been presented on 13th International BRD GAMBIT 2020 Conference and is co-funded by the Science Excellence programme of the Ministry of Science and Higher Education.

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