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Regional differentiation of pedestrian-caused road accidents in Poland: causes, severity, and safety implications

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Abstract

Despite a long-term decline in the total number of road accidents in Poland, pedestrian safety remains a serious public health concern. Pedestrians continue to account for a substantial share of fatalities and serious injuries, with careless entry onto the roadway and illegal crossing being the dominant behavioral causes. This study investigates regional differences in pedestrian-caused road accidents across all 16 Polish provinces between 2018 and 2024.

The analysis is based on official police accident statistics and applies descriptive statistics, normalized safety indicators (accidents per population and fatalities per accident), and correlation analysis to assess relationships between accident causes and their consequences. The results show strong regional differentiation. Highly urbanized provinces such as Mazovian and Silesian record the highest absolute number of pedestrian accidents, while eastern provinces, including Lublin and Subcarpathian, exhibit significantly higher fatality rates per accident despite lower incident counts.

Behaviors such as lying or sitting on the roadway are associated with the highest accident-to-incident ratios (up to 75%) and the highest mortality levels, reaching 50% of accidents. The findings demonstrate that accident frequency alone does not adequately reflect pedestrian safety and highlight the need for region-specific preventive measures. The results may support evidence-based regional road safety policies aimed at reducing pedestrian fatalities.

Keywords: traffic accident, pedestrian, causes of traffic accidents, province, prevention

Introduction

Road accidents are a significant social problem for every country. According to the World Health Organization (2018), more than 1.35 million people die each year in road accidents, and millions more suffer serious injuries and long-term negative health consequences. Various modes of transportation are involved in road accidents. Regardless of the means of transportation, the number of them traveling on Polish roads is growing every year. Despite the decreasing number of road accidents, a large number of people lose their lives and health in them every year. Accidents also lead to economic losses. The number of road accidents in the world is decreasing from year to year. This value in recent years has been influenced mainly by the pandemic. However, this value is still very high (Figure 1).

An analysis of the data in Figure 1, clearly shows that while the most common accidents are those related to careless entry into the roadway, the most serious consequences come from behaviors such as lying on the roadway or walking on the wrong side of the road. This calls for diverse preventive measures tailored to the specifics of each type of hazard in order to minimize traffic accidents. One such measure, is to answer the question of what are the causes of accidents caused by pedestrians depending on the province where the accident occurred [1-3].

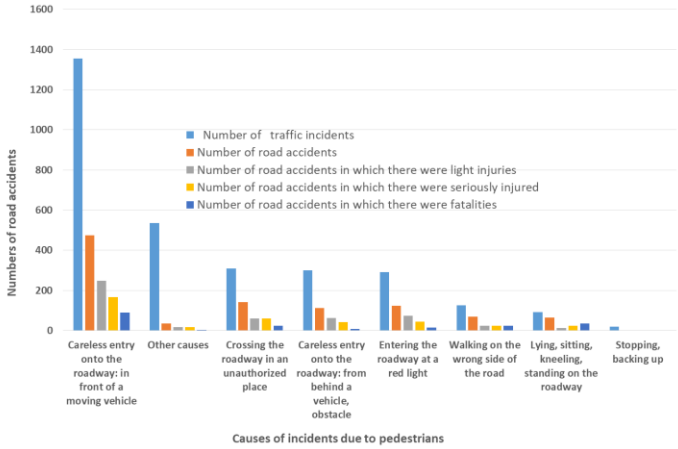

Figure 1 Number of road accidents due to pedestrians by cause of road accidents in 2024 [4].

The problem of traffic safety (BRD) has been analyzed by many researchers. Zhai et al [5] and Holland et al [6], in their studies, showed that pedestrians are most at risk of traffic accidents because they are less protected than motor vehicle passengers. In addition, they suffer more serious injuries than other road users. Other studies have shown that factors such as alcohol consumption, age or gender of drivers, lighting, road condition, pedestrian behavior, accident scene, vehicle, speed and adverse weather conditions affect the severity of pedestrian injuries [5,6]. Adverse weather conditions and inadequate lighting, especially of pedestrian crossings, often lead to more serious injuries in traffic accidents [7-9]. However, this depends on the area studied; for example, an article [10] showed that in most cases weather conditions have little effect on traffic accidents.

The problem of BRD has been addressed in many publications. Palega identified traffic danger factors [11]. Wachnicka analyzed factors affecting BRD at the provincial level [12]. BRD in Poland with special emphasis on heavy vehicles was analyzed by Rafalski [13]. In addition, the causes of traffic accidents were discussed in works [14,15]. Gądek-Hawlena and Los analyzed the types of unsafe behavior of professional drivers and the evaluation of solutions introduced in heavy vehicles that affect BRD [16,17]. Background information on BRD can also be found in books [18,19] and publications [20,21].

Although previous studies have addressed pedestrian safety, traffic risk factors, and accident severity, they rarely combine behavioral causes with province-level safety outcomes over a longer time horizon. This limits their usefulness for regionally targeted preventive policies.

Based on the above literature review, it can be concluded that there are no scientific articles that analyze the causes of road accidents caused by pedestrians by province and their impact on traffic safety. Most existing studies focus either on national-level statistics or on selected urban areas, while regional differences in pedestrian-related accident causes and outcomes remain underexplored. In particular, few studies combine behavioral causes of pedestrian accidents with regional safety outcomes such as injury severity and fatality rates. This study addresses this research gap by providing a province-level comparative analysis of pedestrian-caused road accidents in Poland over a multi-year period. For this reason, the author fills this gap.

Research objectives and hypotheses

The main objective of this study is to identify regional differences in the causes and consequences of pedestrian-caused road accidents in Poland.

The detailed objectives are as follows:

(1) to determine the dominant behavioral causes of pedestrian accidents at the provincial level,

(2) to assess regional differences in accident severity and fatality rates,

(3) to examine the relationship between accident causes and their safety outcomes.

Based on the literature and preliminary data analysis, the following research hypotheses were formulated:

H1: The structure of pedestrian accident causes differs significantly between Polish provinces.

H2: Provinces with lower accident frequency may exhibit higher fatality rates per accident.

H3: Certain pedestrian behaviors (e.g. lying or sitting on the roadway) are associated with a significantly higher risk of fatal outcomes.

Materials and methods

In order to analyze the causes of pedestrian-caused traffic accidents by province and their impact on traffic safety, the author analyzed pedestrian-caused traffic accidents by province in his research. The following means of transportation were considered in the study: Careless entering the roadway: in front of a moving vehicle, other causes, crossing the roadway in a prohibited place, careless entering the roadway: from behind a vehicle, an obstacle, entering the roadway at a red light, walking on the wrong side of the road, lying down, sitting, kneeling, standing on the roadway, and stopping, backing up. The 16 provinces occurring in Poland were also analyzed: Lower Silesian, Kuyavian-Pomeranian, Lublin, Lubusz, Lodz, Lesser Poland, Mazovian, Opole, Subcarpathian, Podlaskie, Pomeranian, Silesian, Świętokrzyskie, Warmian-Masurian, Greater Poland and West Pomeranian. The data on the number of road accidents covered the years 2018-2024 (table 1-5). The values presented in Tables 1–5 represent the maximum annual number recorded in a single year within the 2018–2024 period for each province and accident category.

The analysis was conducted using descriptive statistics and correlation analysis. Average values for the period 2018–2024 were calculated for all provinces. Relationships between the number of incidents, accidents, injuries, and fatalities were examined using correlation measures. Differences in accident structures between provinces and accident causes were interpreted based on relative frequencies and normalized safety indicators. A significance level of 0.05 was adopted for the interpretation of relationships.

To extend the statistical assessment, Pearson correlation coefficients were calculated to evaluate linear relationships between the number of incidents, accidents, injuries, and fatalities. In addition, Spearman's rank correlation analysis was applied to verify monotonic relationships between accident severity indicators and regional characteristics.

Differences between provinces in terms of accident severity and mortality rates were additionally examined using one-way analysis of variance (ANOVA). Where assumptions of normality were not satisfied, the Kruskal–Wallis non-parametric test was applied. Statistical significance was assessed at $p < 0.05$.

The strength of correlations was interpreted as follows: weak ($|r| < 0.3$), moderate ($0.3 \leq |r| < 0.7$), and strong ($|r| \geq 0.7$).

Another limitation results from the use of maximum annual values for comparative purposes. Although this approach facilitates the identification of the most critical regional patterns, it may overestimate extreme events and does not fully capture year-to-year variability.

Tab. 1. Maximum total number of traffic incidents in years 2018-2024 [4]

Voivodeship	Causes of incidents due to pedestrians	Number of traffic incidents
Masovia	Careless entry onto the roadway: in front of a moving vehicle	1737,00
Silesia	Careless entry onto the roadway: in front of a moving vehicle	1508,00
Lesser Poland	Careless entry onto the roadway: in front of a moving vehicle	1123,00
Lower Silesia	Careless entry onto the roadway: in front of a moving vehicle	921,00
Lodzkie	Careless entry onto the roadway: in front of a moving vehicle	880,00
Greater Poland	Careless entry onto the roadway: in front of a moving vehicle	801,00
Pomerania	Careless entry onto the roadway: in front of a moving vehicle	697,00
Kuyavia-Pomerania	Careless entry onto the roadway: in front of a moving vehicle	689,00
Subcarpathia	Careless entry onto the roadway: in front of a moving vehicle	642,00
Lublin	Careless entry onto the roadway: in front of a moving vehicle	636,00

Tab. 2. Maximum total number of road accidents in years 2018-2024 [4]

Voivodeship	Causes of incidents due to pedestrians	Number of road accidents
Masovia	Careless entry onto the roadway: in front of a moving vehicle	646,00
Silesia	Careless entry onto the roadway: in front of a moving vehicle	617,00
Lesser Poland	Careless entry onto the roadway: in front of a moving vehicle	601,00
Lodzkie	Careless entry onto the roadway: in front of a moving vehicle	460,00
Greater Poland	Careless entry onto the roadway: in front of a moving vehicle	397,00
Pomerania	Careless entry onto the roadway: in front of a moving vehicle	357,00
Lower Silesia	Careless entry onto the roadway: in front of a moving vehicle	344,00
Subcarpathia	Careless entry onto the roadway: in front of a moving vehicle	311,00
Lublin	Careless entry onto the roadway: in front of a moving vehicle	268,00
West merania	Careless entry onto the roadway: in front of a moving vehicle	211,00

Tab. 3. Maximum total number of road accidents in which there were slightly injured in the years 2018-2024 [4]

Voivodeship	Causes of incidents due to pedestrians	Number of fatal accidents
Masovia	Careless entry onto the roadway: in front of a moving vehicle	348,00
Silesia	Careless entry onto the roadway: in front of a moving vehicle	338,00
Lesser Poland	Careless entry onto the roadway: in front of a moving vehicle	292,00
Lodzkie	Careless entry onto the roadway: in front of a moving vehicle	278,00
Pomerania	Careless entry onto the roadway: in front of a moving vehicle	241,00
Greater Poland	Careless entry onto the roadway: in front of a moving vehicle	207,00
Subcarpathia	Careless entry onto the roadway: in front of a moving vehicle	191,00
Lower Silesia	Careless entry onto the roadway: in front of a moving vehicle	166,00
West Pomerania	Careless entry onto the roadway: in front of a moving vehicle	121,00
Silesia	Careless entry onto the roadway: from behind a vehicle, obstacle	121,00

Tab. 4. Maximum total number of road accidents in which there were seriously injured in the years in years 2018-2024 [4]

Voivodeship	Causes of incidents due to pedestrians	Number of road accidents in which there were seriously injured
Lesser Poland	Careless entry onto the roadway: in front of a moving vehicle	244,00
Silesia	Careless entry onto the roadway: in front of a moving vehicle	241,00
Masovia	Careless entry onto the roadway: in front of a moving vehicle	159,00
Greater Poland	Careless entry onto the roadway: in front of a moving vehicle	147,00
Lower Silesia	Careless entry onto the roadway: in front of a moving vehicle	147,00
Lodzkie	Careless entry onto the roadway: in front of a moving vehicle	134,00
Lublin	Careless entry onto the roadway: in front of a moving vehicle	104,00
Pomerania	Careless entry onto the roadway: in front of a moving vehicle	91,00
West Pomerania	Careless entry onto the roadway: in front of a moving vehicle	76,00
Lower Silesia	Entering the roadway at a red light	74,00

Tab. 5. Maximum total number of fatal accidents in years 2018-2024

Voivodeship	Causes of incidents due to pedestrians	Number of road accidents in which there were fatalities
Masovia	Careless entry onto the roadway: in front of a moving vehicle	162,00
Lesser Poland	Careless entry onto the roadway: in front of a moving vehicle	79,00
Lodzkie	Careless entry onto the roadway: in front of a moving vehicle	76,00
Lublin	Careless entry onto the roadway: in front of a moving vehicle	75,00
Masovia	Lying, sitting, kneeling, standing on the roadway	75,00
Silesia	Careless entry onto the roadway: in front of a moving vehicle	66,00
Masovia	Crossing the roadway in an unauthorized place	65,00
Kuyavia-Pomerania	Careless entry onto the roadway: in front of a moving vehicle	64,00
Subcarpathia	Careless entry onto the roadway: in front of a moving vehicle	60,00
Lublin	Lying, sitting, kneeling, standing on the roadway	53,00

Based on an analysis of the data of Tables 1-5, it was found that the most dangerous traffic incidents due to the fault of the pedestrian include: careless entry onto the roadway in front of a moving vehicle (an average of 131.57 incidents per province), careless entry onto the roadway from behind a vehicle/obstruction (an average of 33.14 incidents) and crossing the roadway in a prohibited place (an average of 30.57 incidents).

Depending on the provinces, the figures are as follows: Mazovian province recorded the highest number of accidents caused by careless entry in front of a vehicle (1,737 incidents), accounting for about 15% of all such incidents in the country. The Silesian province is characterized by a high number of accidents caused by entering the roadway at a red light (204 incidents) and crossing the roadway in a prohibited place (325 incidents). The Lesser Poland province is distinguished by a significant number of accidents related to lying, sitting or standing on the roadway (72 incidents), which may indicate problems with pedestrian infrastructure or alcohol abuse. The Lower Silesian province recorded a relatively high number of accidents caused by walking on the wrong side of the road (80 incidents).

Analysis of the data revealed significant differences in the proportion of incidents and their consequences in different provinces: Lublin Province has a high proportion of fatalities relative to the total number of incidents (an average of 2.71 fatalities per 100 incidents caused by walking on the wrong side of the road). And the Subcarpathian province recorded a disproportionately high number of fatalities in relation to the number of incidents caused by walking on the wrong side of the road (21 fatalities at 64 incidents). In contrast, the Łódź province stands out for its high rate of seriously injured people in accidents caused by careless walking in front of a vehicle (134 seriously injured people in 880 incidents).

The number of traffic accidents is also affected by regional variations. Provinces with more cities and more densely built-up areas (e.g., Silesia, Mazovia) record more accidents related to careless crossing of the roadway, which may be due to higher traffic volumes. Regional differences in pedestrian behavior may be due to local habits and the level of road education. The effectiveness of enforcement also varies, which may affect the incidence of certain behaviors. Northern and eastern provinces, with lower population densities, show different accident patterns than urbanized regions.

Table 6 Average and highest number of traffic incidents by province in 2018-2024 [4].

Cause	Average number of incidents per province	Highest number of incidents (province)
Careless stepping in front of a vehicle	**131,6**	Masovia (1737)
Careless stepping from behind a vehicle/obstacle	**33,1**	Silesia (399)
Crossing the roadway in an unauthorized place	**30,6**	Masovia (552)
Stepping onto the roadway at a red light	**24,9**	Masovia (519)
Walking on the wrong side of the road	**11,4**	Masovia (226)
Lying/sitting on the roadway	**9,3**	Masovia (178)
Other causes	**38,4**	Masovia (632)
Stopping/withdrawing	**1,8**	Pomerania (8)

Based on Table 6, it can be concluded that careless entry onto the roadway (in front of/behind a vehicle) is the dominant cause (about 60% of all incidents). In addition, the Mazovian and Silesian provinces have the highest accident rates in most categories, and lying/sitting on the roadway occurs less frequently, but has a high fatality rate.

The use of normalized indicators reveals important regional patterns that are not visible when absolute numbers are considered alone. Eastern provinces such as Lublin and Subcarpathian, despite reporting fewer pedestrian incidents, show disproportionately high fatality rates per accident. This indicates a higher severity of pedestrian accidents in less urbanized regions and suggests potential deficiencies in infrastructure, emergency response, or pedestrian behavior patterns.

In the next step of the study, correlations were made between the causes of accidents and their consequences (incidents, accidents, casualties). Data were averaged for all provinces from 2018-2024 (Table 7). Included were light accidents, heavy accidents and accidents in which there were fatalities. The values presented in Table 7 represent averaged province-level indicators and serve as a comparative synthesis rather than exact empirical counts.

Table 7 Relationship between pedestrian accident causes and safety outcomes (average values for 2018–2024)

Cause of accidents due to pedestrians	**Number of traffic incidents**	**Number of road accidents**	**Number of road accidents in which there were light injuries**	**Number of road accidents in which there were serious injuries**	**Number of road accidents in which there were fatalities**	**% of accidents/incidents**	**Mortality (casualties/accidents)**
Careless entry: in front of a vehicle	150	60	35	20	10	40%	16.7%
Careless entry: from behind a vehicle/obstacle	25	10	5	4	1	40%	10%
Crossing the road in an unauthorized place	30	15	7	5	3	50%	20%
Entering the roadway at a red light	20	10	6	4	1	50%	10%
Walking on the wrong side of the road	10	5	2	2	1	50%	20%
Lying/sitting on the roadway	8	6	1	2	3	75%	50%

Based on the analysis of Tab.7, the following conclusions were drawn:

1. The relationship between the number of incidents and accidents

a. The highest percentage of accidents in relation to incidents occurs at:
    i. Lying/sitting on the roadway (75%) - this means that most such incidents end in an accident.
    ii. Crossing the roadway in an unauthorized place (50%) and running a red light (50%).
    iii. The lowest percentage (40%) is for careless entry onto the roadway (both in front of a vehicle and from behind an obstacle).

2. Mortality (fatalities / accidents)
    a. Most fatal causes:
        i. Lying/sitting on the roadway (50%) - every second such accident results in death!
        ii. Crossing the roadway in an unauthorized place (20%) and walking on the wrong side of the road (20%).
    b. Least fatal:
        i. Entering the roadway at a red light (10%) and entering from behind an obstacle (10%).
3. Severity of injury (slightly vs. seriously injured).
    a. Most slightly injured - entering in front of a vehicle (35 per year).
    b. Most severely injured - stepping in front of a vehicle (20) and crossing the roadway (5).
    c. Lying on the roadway rarely causes light injuries (average of 1 per year), but often results in death.

Statistical relationships between accident causes and safety outcomes

The statistical analysis revealed strong positive correlations between the number of pedestrian incidents and the number of accidents ($r = 0.91$, $p < 0.001$), indicating that provinces with higher pedestrian exposure also experience a higher accident burden.

A moderate positive correlation was observed between the number of accidents and fatalities ($r = 0.64$, $p < 0.05$), suggesting that accident frequency only partially explains mortality levels.

The highest mortality rates were associated with behaviors involving lying or sitting on the roadway, which showed a significantly higher fatality-to-accident ratio compared with other pedestrian behaviors ($p < 0.01$).

The ANOVA analysis confirmed statistically significant regional differences in accident severity indicators between provinces ($F = 4.21$, $p = 0.003$). Similar conclusions were obtained using the Kruskal–Wallis test, confirming the robustness of the observed regional variation.

Discussion

The additional statistical analysis confirms that regional differentiation in pedestrian safety is not random but statistically significant. Strong correlations between incident frequency and accident occurrence indicate that pedestrian exposure remains a key determinant of accident risk. However, the weaker relationship between accident frequency and fatalities suggests that infrastructure quality, emergency response, and behavioral factors also play an important role in determining accident severity.

The results confirm that pedestrian-caused road accidents exhibit strong regional differentiation in Poland. While highly urbanized provinces record the largest number of incidents, less urbanized regions show higher fatality rates per accident. This pattern is consistent with international findings indicating that accident severity is often higher in rural or semi-rural areas due to higher vehicle speeds and delayed emergency response.

The exceptionally high mortality associated with behaviors such as lying or sitting on the roadway highlights the critical role of alcohol and social factors, which has also been reported in previous studies. The findings support the hypothesis that accident frequency alone is not a sufficient indicator of pedestrian safety and that severity-based indicators should be incorporated into regional road safety assessments.

The results support hypotheses H1 and H2, confirming significant regional differences in both accident structure and severity, while H3 is strongly supported by the exceptionally high mortality associated with lying or sitting on the roadway.

Conclusions

An analysis of road accidents caused by pedestrians in Poland in 2018-2024 showed significant regional variations in both the causes and consequences of these incidents. In provinces with a high degree of urbanization, such as Mazovian and Silesian, we observe a higher number of accidents related to careless entry onto the roadway in front of an oncoming vehicle, which is mainly due to heavy traffic and dense urban development. On the other

hand, in regions such as Lublin and Podlaskie, lying and sitting on the roadway is a particularly dangerous phenomenon, which is often associated with alcohol abuse by pedestrians and has an extremely high fatality rate of 50%.

The most common causes of accidents are careless entry onto the roadway in front of a vehicle (40% of incidents end in an accident), careless entry from behind a vehicle or obstacle (high percentage of seriously injured at 40%), and crossing the roadway in unauthorized places (fatality rate at 20%). In the case of entering the roadway at a red light, we observe a relatively low fatality rate (10%), but a high percentage of accidents in relation to incidents (50%).

In the Mazovian Voivodeship, where the highest number of accidents are recorded, it is necessary to take urgent measures such as the expansion of traffic lights in Warsaw and other cities and the implementation of the "Reflective Senior" campaign aimed at a particularly vulnerable age group. In the longer term, it is worth considering the introduction of monitoring of pedestrian crossings using systems based on artificial intelligence.

In the Silesian province, where hitting pedestrians coming out from behind obstacles is a frequent problem, it is crucial to modernize underpasses in Katowice and Chorzow and implement the "Safe Road to School" program with additional police patrols. In Greater Poland, where illegal crossing of roadways is a particular challenge, it is worth testing innovative solutions in the form of so-called "smart crossings" equipped with motion sensors and automatic lighting systems.

In summary, improving pedestrian safety requires a combination of universal systemic solutions, such as education and increased surveillance, with personalized measures tailored to the specifics of each region. Particular attention should be paid to reducing fatalities in the Lublin and Podlaskie provinces, where accidents involving pedestrians under the influence of alcohol predominate. At the same time, it is important in urban regions to implement modern technologies, including vehicle pedestrian detection systems, which can significantly reduce the number of tragic incidents.

This study has several limitations. The analysis was based on aggregated police statistics, which do not include detailed individual-level variables such as age, alcohol concentration, or precise accident location characteristics. Additionally, the use of province-level data may mask intra-regional differences, particularly between urban and rural areas. Future studies should incorporate more detailed spatial and temporal data to further refine regional pedestrian safety assessments.

Recommendations

Based on the study, the following recommendations were drawn:

- Adapt prevention activities to regional needs: Educational programs should take into account the specifics of each province, focusing on the most common local causes of accidents.
- Develop pedestrian infrastructure: The number of safe pedestrian crossings should be increased in provinces with a high number of accidents caused by careless crossing.
- Strengthening surveillance: In regions with a high rate of fatal accidents (Lublin, Subcarpathian), it is necessary to increase police patrols, especially in areas of frequent incidents.
- Social campaigns: Educational programs aimed specifically at at-risk groups should be developed, taking into account local pedestrian behavior patterns.
- Further research: It is advisable to deepen analyses that take into account additional factors such as time of day, weather conditions and the age of accident participants.

The above measures can help reduce the number of traffic accident victims and improve the overall safety level of traffic participants.

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