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# Road Accidents in Poland in the Context of Selected Factors and Dynamic Development of Motorization

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**Abstract.** The increase in mobility in Poland is one of the most visible manifestations of the country's dynamic socio-economic development since joining the European Union in 2004. This phenomenon reflects both technological advances and the changing needs and expectations of citizens. The increasing number of vehicles, and thus traffic participants, poses numerous challenges to society and authorities in particular in the context of ensuring traffic safety. The publication conducted a study of the impact of calendar-related factors (day of the week, month) on the number of accidents in Poland. The purpose of the article was to assess, whether these are significantly influential factors and to present the issue of road accidents in the context of the current state of road safety in Poland as measured by the number of victims and injuries. The number of accidents was shown to be significantly dependent on the month, as well as the day of the week. Attention was also paid to the issue of the severity of accidents in Poland compared to other EU countries, in view of which recommendations aimed at minimizing the number of victims were indicated.

**Keywords.** Road accidents, road safety, factors, motorization development, Poland

## 1. Introduction

The noticeable increase in mobility in Poland is driven by rising societal wealth, technological advancements that lower vehicle costs, globalization, and the need for jobs across various regions, coupled with improvements in transport infrastructure. As a result, an increasing number of people have access to vehicles and the need to travel long distances, and this makes the issue of traffic safety invariably topical, and continuous research is needed to reduce the risk of traffic accidents and implement effective countermeasures and regulatory measures, both in the technical and legal spheres [1,2]. Road safety has been a longstanding priority in many countries, including Poland, the focus of this study. Road accidents stem from numerous and diverse causes. Among them are: inadequate training and lack of effective awareness of the consequences of incidents, technical efficiency of vehicles, and the state of road

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infrastructure. Factors beyond human control such as weather conditions and time of day or time of the year variables also significantly impact accident rates.

This study investigates the influence of calendar factors, specifically whether accident frequencies correlate with particular months or days of the week. The purpose of the article is to assess whether these are factors that significantly affect the number of events. Such an analysis also indirectly provides information regarding the impact of traffic volume, which is currently not measured on most road sections in Poland. Therefore, analyses to infer traffic variability from other factors are important. Additionally, the article discusses road accidents within the current context of Polish road safety, quantified by casualties and injuries. The structure of the article is as follows. First, the characteristics of Poland compared to other European Union countries in terms of the number of vehicles and traffic accidents are presented. The main causes of accidents and their consequences are also indicated. A study of the influence of calendar-related factors (day of the week, month) on the number of accidents in Poland was then conducted. It ends with conclusions and recommendations aimed at minimizing the drastic effects of accidents on the roads. The analysis was conducted for Poland, but both the evaluation method and the conclusions obtained are universal and applicable to any country.

## 2. Literature review

The topic of traffic safety in Poland is popular in the literature, especially in the context of traffic accidents and their effects on participants [3]. The authors of the publication mainly focus on analyses of injured and casualties by year, while making comparisons (for example, against the EU) and pointing out changing trends [4,5]. The causes of traffic accidents are equally often addressed [6]. The relationship between weather conditions and the number of accidents is mainly analyzed [7,8]. It is stressed that in addition to the weather, driver behavior and traffic volume, which determines, among other things, the increase in the total number of vehicles on the road, have an impact on the increase in incidents [9]. In addition, the number of accidents has been shown to depend on the time of day [10]. Other studies have confirmed that driver assistance systems have a significant impact on improving road safety [11].

Many authors use mathematical modeling to assess the current level of road safety [12, 13]. In doing so, they also point to the significant changes that are taking place in the area of traffic safety [14]. Due to the multitude of factors that determine the occurrence of accidents, a methodology for optimizing them is proposed [15]. There are also published works indicating possible solutions and areas that should be improved to increase the safety of traffic participants [16, 17]. An extremely popular issue in recent years has been the "Vision Zero" strategy of using all available methods and means to almost completely minimize injuries and casualties [18]. It is pointed out that complementary to the achievement of this goal can be infrastructure development, legislative action by the authorities, international cooperation, and the implementation of innovative technologies in vehicles, among others [19, 20]. Less attention, however, has been paid to research on the impact of calendar-related factors on the number of accidents in the context of dynamic motorization, which has become the subject of this publication. The days of the week also reflect to some extent the volume of traffic on the roads, which in many places is not measured in any way. This provides additional findings in the study.

## 3. Materials and methods

In Poland, information on traffic incidents is collected by the Police in the Accident and Collision Register (SEWiK). This study was based on road accident databases from 2014 to 2023 [21].

The article evaluates the impact of selected factors on traffic accidents. The variables chosen were those related to the calendar, i.e. month and day of the week. The Kruskal-Wallis test was used for the study. In this test, for the trait under study $X$ a sample is taken for $k$ groups. Let $x_i = \{x_{i1}, x_{i2}, \dots, x_{i,n_i}\}$ denote the realization for $i$-th group and $i = 1,2,\dots,k$, while let $F_i(x)$ denote the distribution for $i$-th group. A working hypothesis is created at the significance level $0 < \alpha < 1$:
$H_0: F_1(x) = F_2(x) = \cdots = F_k(x)$ — distributions in the groups are identical or differ nonsignificantly, against the alternative hypothesis:
$H_1$ — there are such $i, j$ that $F_i(x) \neq F_j(x)$ — distributions within the groups differ significantly.

The test statistics is described by the following the formula:

$$T = \frac{12}{n(n+1)} \sum_{i=1}^{k} n_i \left( \overline{R}_i - \frac{n+1}{2} \right)^2, \quad (1)$$

and has a distribution $\chi^2$ with $(k-1)$ degrees of freedom. $R_{ij}$ denotes the rank for the element $x_{ij}$, $1 \leq i \leq k, 1 \leq j \leq n_i$.

The critical set is of the form $W = [\chi^2_{1-\alpha}(k-1), +\infty)$, where $\chi^2_{1-\alpha}(k-1)$ is the quantile of the order $1-\alpha$ for the distribution $\chi^2$ with $k-1$ degrees of freedom. If $T \in W$ then at the level of significance $\alpha$ we reject $H_0$ in favor of the alternative hypothesis $H_1$, the distributions in the groups differ significantly.

## 4. Road accidents in Poland compared to other countries

Automobile development can be observed by referring, among other things, to data on the number of vehicles in operation in a given country or region. Therefore, this analysis is made with reference to the European Union. The increasing number of vehicles is an indication of the country's economic development, the growth of society's wealth and an overall improvement in the quality of life. Based on the data from 2022, it can be concluded that the largest number of vehicles in the European Union is used in France - 5.75 million, in Italy - 5.37 million and in Poland - 4.5 million. In contrast, in most EU countries, the values did not exceed 1.3 million.

During the period under consideration, a number of member countries saw an increase in the number of vehicles, including Italy, Romania, Croatia and Estonia. Of particular note, however, is the clearly visible upward trend in the number of vehicles in Poland, which, throughout the entire period under review, was not disrupted by the socio-economic crises taking place at the time, nor by the outbreak of the COVID-19 pandemic (Figure 1). From 2013 to 2022, the number of vehicles in Poland increased by as much as 1.1 million (+32.29%). This rapid growth means that the mobility of the population is improving year after year, especially in regions with poor access to public transportation. Investment attractiveness is also increasing, as the availability of road transportation facilitates the movement of goods and people, which in turn promotes the development of trade, which in turn translates into economic growth for the country.

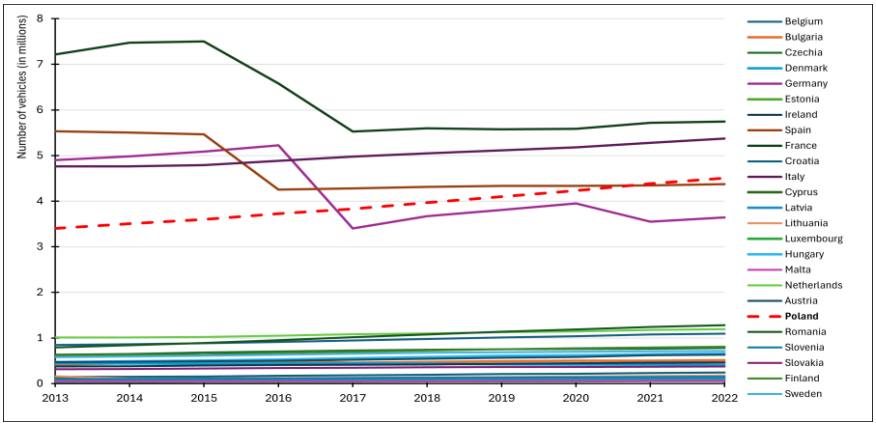


**Figure 1.** Number of vehicles in Poland compared to other EU countries in 2013–2022 [22].

The increase in the number of vehicles is a positive development that means that transportation is more accessible to people, thus improving their mobility and enabling them to travel more easily. However, the greater number of cars on the road translates into a greater number of traffic participants, which in turn has a significant impact on safety, as it increases the likelihood of a collision or accident. Nevertheless, the main causes of dangerous traffic incidents include failure to comply with current laws, speeding, driving under the influence of intoxicants, failure to adjust speed to weather and road conditions, as well as the improper technical condition of vehicles in operation [3, 23, 24]. Taking into account the number of accidents in each country, it is advisable to refer to the size of the country's population when doing so. Based on data from 2013 to 2022, the relationship is particularly unfavorable in EU countries such as Austria, Germany, Portugal and Belgium. Moreover, since the outbreak of the COVID-19 pandemic, there has been an upward trend in these countries. In Poland, on the other hand, the ratio was 566 in 2022, and has been on a downward trend since 2019, which is a welcome development (Fig. 2). However, despite the positive results, the issue of traffic accidents should not be underestimated and consistently strive to minimize the number of these incidents and their consequences.

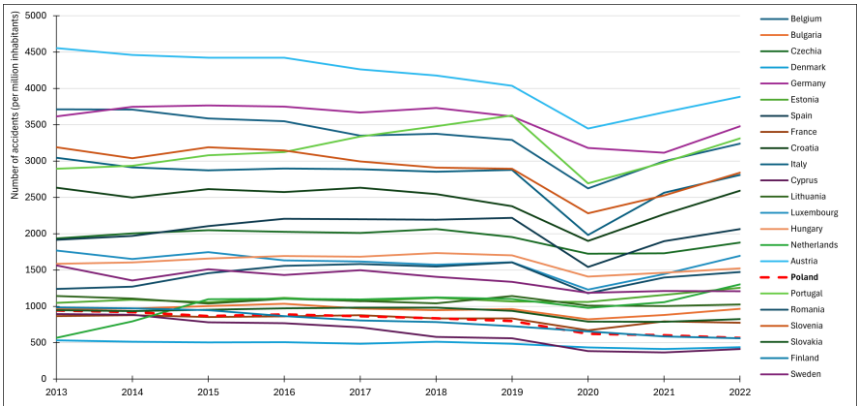


**Figure 2.** Number of road accidents in Poland compared to other EU countries in 2013–2022 [25].

Road accidents are serious in their consequences, as they lead to injuries and often even death, so that in addition to the participants, their families and loved ones are also affected. Witnesses to accidents, on the other hand, may experience psychological disturbances and even feel fearful of traveling. It is also worth noting that these incidents generate huge economic costs in terms of repairing damaged vehicles and breached infrastructure, treating the injured, or loss of income due to inability to work. In addition, as a result of dangerous traffic incidents, a serious strain is put on the health care system not only because of the need for medical interventions, but especially when long-term treatment or rehabilitation is required [26]. Therefore, it can be concluded that traffic accidents are an undesirable phenomenon for both the state's economy and the population, because in addition to material losses, they have a negative impact on the sense of security among the public.

In 2022, the highest number of traffic accidents occurred in Germany — 289,672, in Italy — 165,889 and in Spain — 97,916. In comparison, there were 21,322 such incidents in Poland. The highest number of people killed in 2022 was recorded in France with 3,260, Italy with 3,159, Germany with 2,788 and Poland with 1,896. The largest number of road users were injured as a result of accidents occurring in Germany — 361,134, Italy — 223,475 and in Spain — 127,830. Poland was ranked tenth in the list with a score of 24,743. In 2022, the highest rate of fatalities per 100 road accidents was recorded in Cyprus — 9.9 and Poland — 8.9 (Fig.3). The highest rate of injuries per 100 traffic accidents was recorded in Italy, with 134.7, and Croatia, with 133.2. In Poland, by contrast, the ratio was 116.0.

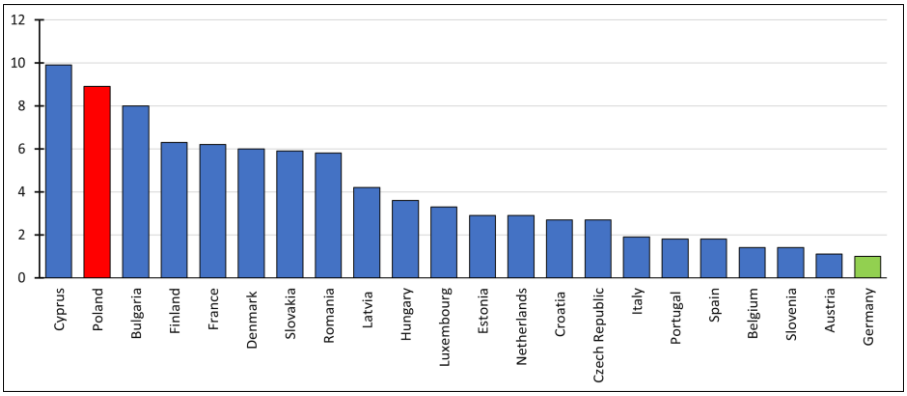


**Figure 3.** Rate of deaths per 100 accidents in EU countries in 2022 [21].

Considering the statistics related to the number of accidents and, in particular, the breakdown of accidents and their consequences (victims and injuries), there is no doubt that there is still a need to prevent such incidents. For this reason, it is reasonable to study the outflow of selected factors on the number of accidents to decide what measures should be taken to increase the level of safety on the roads. The present study, conducted on the example of Poland, also fits into this assumption.

## 5. Study of the impact of selected factors on the number of traffic accidents in Poland

First, a study was made of changes in the number of traffic accidents from 2014 to 2023, which made it possible to note the general trend in the phenomenon. Figure 4 clearly shows a decreasing trend, which is a very positive result, especially in the context of increasing mobility worldwide. The number of victims of these accidents is also decreasing, both in terms of those injured and those killed.

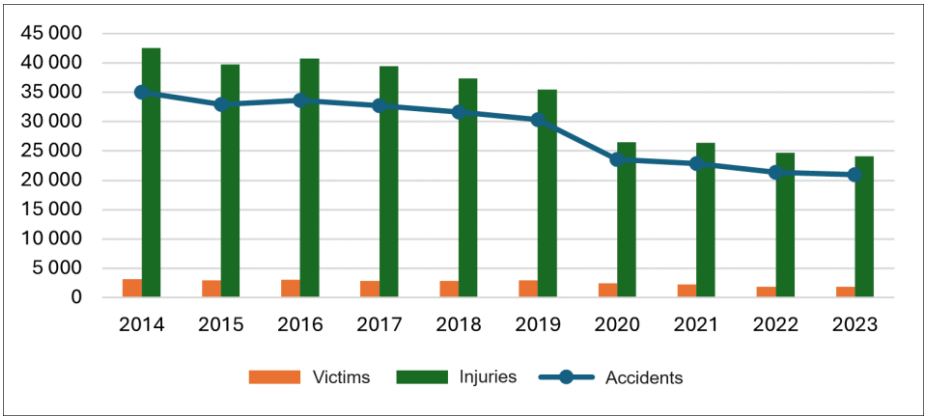


**Figure 4.** Total number of traffic accidents and their victims from 2014 to 2023.

The number of accidents was then analyzed in relation to the month of the incident. First, the number of accidents in the groups designated by the month of the event was checked to see if the number of accidents followed a normal distribution. The results are presented in Table 1.

**Table 1.** Lilliefors test results for the number of accidents in Poland by month

| Mo. | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| D | 0.058 | 0.042 | 0.032 | 0.068 | 0.033 | 0.044 | 0.043 | 0.048 | 0.034 | 0.044 | 0.043 | 0.080 |
| p-val | 0.013 | 0.267 | 0.598 | 0.002 | 0.562 | 0.167 | 0.176 | 0.077 | 0.562 | 0.160 | 0.189 | $5.4\times10^{-5}$ |

Since conformity to a normal distribution was not confirmed for all distributions, the Kruskal-Wallis test, which does not require meeting this assumption, was used to test the effect of the month variable on the number of traffic accidents. Kruskal-Wallis test statistic T = 914.13 and p-value = $2.2\times10^{-16}$. The distributions within the groups differ significantly. The result obtained is confirmed by the differences seen in Figure 5.

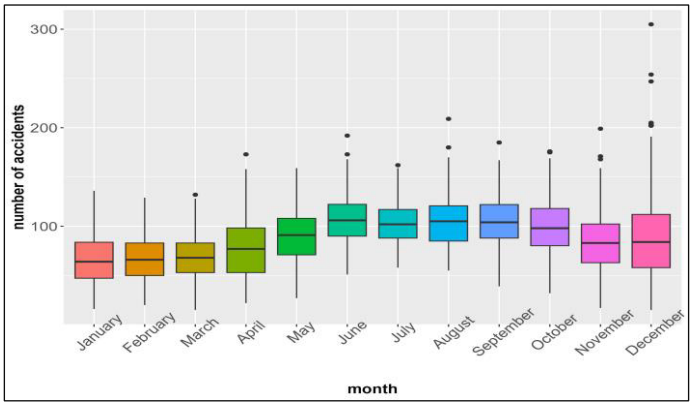


**Figure 5.** Box plot of the number of traffic accidents by month.

The aforementioned analysis shows that the month variable significantly affects the number of accidents. Most accidents occur during the holiday months, i.e. from June to October. This is due to the increased movement of people due to connection with leaves and vacations. The median values for November and December are also quite high. This is probably due to the holidays taking place in Poland during these months — All Saints' Day, Day of the Dead and also Christmas.

A factor that can also affect the number of traffic accidents is the day of the week. Analogous to months, the distributions determined by the day-of-week variable were first checked for consistency with a normal distribution. The results are presented in Table 2.

**Table 2.** Lilliefors test results for the number of accidents in Poland by day of the week

| Month | Mon | Tue | Wed | Thu | Fri | Sat | Sun |
|---|---|---|---|---|---|---|---|
| **D** | 0.06 | 0.031 | 0.029 | 0.04 | 0.034 | 0.039 | 0.042 |
| **p-value** | 0.0001 | 0.248 | 0.348 | 0.044 | 0.159 | 0.062 | 0.027 |

Next, a study was made of the effect of the variable month on the number of traffic accidents. The Kruskal-Wallis test statistic was T = 268.77 and p-value = $2.2\times10^{-16}$. Again, the variables in the groups differ significantly. The obtained relationship is confirmed by the box-and-whisker diagram shown in Figure 6.

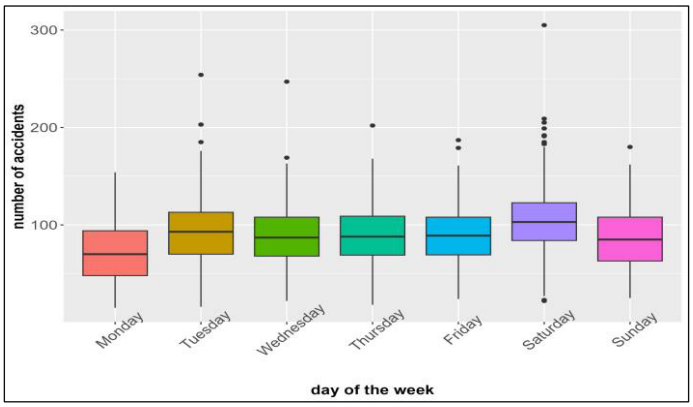


**Figure 6.** Weekly seasonality observed throughout the study period.

Differences by day of the week are evident, although not as pronounced as for months. In the chart above, Friday stands out — as the day with the highest number of accidents on average — and Sunday, when there are the fewest. This relationship may be due to the fact that Friday is the last working day of the week. With the onset of the weekend, people decide to travel away from where they live to relax. This leads to increased traffic on the road, and combined with concentration reduced due to fatigue, can increase the likelihood of accidents. Sunday, on the other hand, is a day off from work, when many Poles travel with their children or stay home spending time with family. This makes the atmosphere on the roads more peaceful, which is consequently reflected in fewer traffic accidents.

## 6. Conclusions

According to the data analyzed, the number of vehicles in Poland has been steadily increasing in recent years, which in turn translates into a greater number of traffic participants, thereby increasing the likelihood of accidents. Considering the number of such incidents per million citizens, Poland, compared to the European Union, has one of the lower ratios showing a decreasing trend in recent years. Of concern, however, is the still exceptionally high rate of deaths per 100 traffic accidents, which clearly indicates the need to increase traffic safety.

The factors that shape traffic safety are elements of the human-road-vehicle system. In addition, the system is influenced by many independent factors — external ones, resulting from the time factor (time of day, season) or meteorological conditions. The survey carried out showed that the number of accidents in Poland is significantly dependent on the month, as most accidents occur during the holiday months (June - October) and the holiday season (November and December). Differences by day of the week are also evident, although not as pronounced as for months. A distinction is made between Friday — as the day with the highest number of accidents on average — and Sunday, when there are the fewest.

In light of the subject matter taken up, additional attention must be paid to the severity of accidents in Poland. There is no doubt that Poland's roads are much safer than they were a decade ago, as the numbers of accidents and victims of traffic incidents

unquestionably show. However, the number of fatalities relative to the number of accidents is still very high in Poland. Far fewer people are killed in EU countries than in Poland. There may be many reasons for this, while the more important ones include the condition and age of the vehicles in operation, which are not equipped with the latest safety systems. It is very common that they are repaired by unauthorized services and unqualified mechanics, which results in the fact, that energy-consuming zones do not work during events. Another aspect is the speed and expertise of first aid in an accident situation. The first few minutes after an incident are crucial, so it is important for other traffic participants to be able to keep the injured alive. It should be pointed out that the goal for Poland in the coming years should be to drastically reduce the ratio of casualties to accidents, allowing the whole society to feel safer on the roads.

## References

[1] Kukulski J, Lewczuk K, Góra I, Wasiak M. Methodological aspects of risk mapping in multimode transport systems. Eksploatacja i Niezawodność - Maintenance and Reliability. 2023;25(1):19. https://doi.org/10.17531/ein.2023.1.19

[2] Niewczas A, Mórawski Ł, Rymarz J., Dębicka E, Hołyszko P. Operational risk assessment model for city buses. Eksploatacja i Niezawodność - Maintenance and Reliability. 2023;25(1):14. https://doi.org/10.17531/ein.2023.1.14

[3] Szumska E, Frej D, Grabski P. Analysis of the Causes of Vehicle Accidents in Poland in 2009-2019. LOGI - Scientific Journal on Transport and Logistics. 2020 Nov;11(2):76-87. https://doi.org/10.2478/logi-2020-0017

[4] Burzyńska M, Pikala M. Decreasing Trends in Road Traffic Mortality in Poland: A Twenty-Year Analysis. International Journal of Environmental Research and Public Health. 2021;18(19):10411. https://doi.org/10.3390/ijerph181910411

[5] Frej D, Ludwinek K. Analysis of road accidents in 2002-2019 on the example of Poland. The Archives of Automotive Engineering - Archiwum Motoryzacji. 2020;89(3):5-18. https://doi.org/10.14669/AM.VOL89.ART1

[6] Gorzelanczyk P, Jurkovič M, Skibińska J, Kalina T. Road safety and the causes of road accidents in Poland. Transport Problems. 2022; 17(3):20-33. https://doi.org/10.20858/tp.2022.17.3.02

[7] Borucka A, Pyza D. Influence of meteorological conditions on road accidents. A model Indexed by: for observations with excess zeros. Eksploatacja i Niezawodność - Maintenance and Reliability. 2021;23(3):586-592. https://doi.org/10.17531/ein.2021.3.20

[8] Becker N, Rust HW, Ulbrich U. Predictive modeling of hourly probabilities for weather-related road accidents. Nat. Hazards Earth Syst. Sci. 2020;20(10):2857-2871. https://doi.org/10.5194/nhess-20-2857-2020

[9] Sánchez González S, Bedoya-Maya F, Calatayud A. Understanding the Effect of Traffic Congestion on Accidents Using Big Data. Sustainability. 2021;13(13):7500. https://doi.org/10.3390/su13137500

[10] Borucka A, Kozłowski E, Oleszczuk P, Świderski A. Predictive analysis of the impact of the time of day on road accidents in Poland. Open Engineering. 2020 Dec;11(1):142-150. https://doi.org/10.1515/eng-2021-0017

[11] Masello L, Castignani G, Sheehan B, Murphy F, McDonnell K. On the road safety benefits of advanced driver assistance systems in different driving contexts. Transp. Res. Interdiscip. Perspect. 2022 Sept;15(1): 100670. https://doi.org/10.1016/j.trip.2022.100670

[12] Borucka A, Grzelak M. Evaluation of road safety in Poland. Journal of Military Logistics Systems. 2019;51(2): 15-25. https://doi.org/10.37055/slw/129218

[13] Murawski J, Szczepański E, Jacyna-Gołda I, Izdebski M, Jankowska-Karpa D. Intelligent mobility: A model for assessing the safety of children traveling to school on a school bus with the use of intelligent bus stops. Eksploatacja i Niezawodność - Maintenance and Reliability. 2022;24(4):695-706. https://doi.org/10.17531/ein.2022.4.10

[14] Jurecki R. Analysis of Road Safety in Poland after Accession to the European Union. Komunikácie - vedecké listy Žilinskej univerzity v Žiline. 2020;22(2):60-67. https://doi.org/10.26552/com.C.2020.2.60-67

[15] Gorzelanczyk P, Tylicki H. Methodology for Optimizing Factors Affecting Road Accidents in Poland. Forecasting. 2023;5(1):336-350. https://doi.org/10.3390/forecast5010018

[16] Subhan F, Zhao S, Diop EB, Ali Y, Zhou H. Public intention to pay for road safety improvement: A case study of Pakistan. Accid Anal Prev. 2021;160 (1):106315. https://doi.org/10.1016/j.aap.2021.106315
[17] Warczek J, Żak K. The assessment of the technical condition of a tire belt using computed tomography. Eksploatacja i Niezawodność - Maintenance and Reliability. 2024;26(2). https://doi.org/10.17531/ein/183177
[18] Jamroz K, Romanowska A, Michalski L, Żukowska J. Vision Zero in Poland. 2022: 1-40. https://doi.org/10.1007/978-3-030-23176-7_14-1
[19] Shen Y, Hermans E, Bao Q, Wets G. Towards better road safety management: Lessons learned from inter-national benchmarking. Accident Analysis & Prevention. 2020 Apr; 138(1):105484. https://doi.org/10.1016/j.aap.2020.105484
[20] Graba M, Bieniek A, Prażnowski K, Hennek K, Mamala J, Burdzik R, Śmieja M. Analysis of energy efficiency and dynamics during car acceleration. Eksploatacja i Niezawodność - Maintenance and Reliability. 2023;25(1):17. https://doi.org/10.17531/ein.2023.1.17
[21] Komenda Główna Policji - Biuro Ruchu Drogowego. Wypadki drogowe w Polsce w 2023 r. Published 2023. Accessed 12 May, 2024. https://statystyka.policja.pl/download/20/423450/Wypadkidrogowe2023.pdf.
[22] Eurostat. Stock of vehicles by category and NUTS 2 regions. Published 5 May, 2024. Accessed 12 May, 2024. https://ec.europa.eu/eurostat/databrowser/view/tran_r_vehst__custom_11434007/default/table.
[23] Karpenko M, Skačkauskas P, Prentkovskis O. Methodology for the Composite Tire Numerical Simulation Based on the Frequency Response Analysis. Eksploatacja i Niezawodność - Maintenance and Reliability. 2023;25(2). https://doi.org/10.17531/ein/163289
[24] Oszczypała M, Ziółkowski J, Małachowski J. Semi-Markov approach for reliability modelling of light utility vehicles. Eksploatacja i Niezawodność - Maintenance and Reliability. 2023;25(2):1 25(2). https://doi.org/10.17531/ein/161859
[25] Eurostat. Road accidents by NUTS 3 regions. Published 12 April, 2024. Accessed 12 May, 2024. https://ec.europa.eu/eurostat/databrowser/view/tran_sf_roadnu__custom_11434272/default/table.
[26] Mayou R, Bryant B. Consequences of road traffic accidents for different types of road user. Injury. 2003 Mar; 34(3): 197-202. https://doi.org/10.1016/S0020-1383(02)00285-1