

Analysis of Road Accidents in Poland and EU Countries in the Context of Implementing Vision Zero

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Abstract

The article presents a comparative analysis of road traffic fatalities in Poland and the European Union (EU-27) in the context of implementing the "Vision Zero" strategy. The study covers the period 2014–2023 and employs absolute and per capita indicators (fatalities per 1 million inhabitants) to assess safety trends. Log-linear models and joinpoint analysis were applied to estimate the average annual percent change (APC) and identify shifts in trend dynamics. Results indicate a significant reduction in road fatalities in Poland (–40.9% absolute, –38.1% per 1 million inhabitants) and in the EU-27 (–15.6% absolute, –16.4% per 1 million inhabitants). The APC in Poland (–5.68% absolute, –5.26% per capita) was more than twice as high as the EU average, with a notable acceleration after 2019, likely influenced by infrastructure improvements, enhanced law enforcement, and pandemic-related traffic reductions. Despite progress, Poland's fatality rate remains slightly above the EU average, highlighting the need for continued system-wide safety measures. The findings demonstrate the effectiveness of a Safe System Approach and provide evidence-based recommendations for achieving the intermediate 2030 targets of Vision Zero.

Keywords

road traffic accidents, Road Safety (RS), Vision Zero, Poland, European Union, fatalities Safe System Approach, trend analysis, joinpoint analysis

1 Introduction

Every year, a significant number of people are killed on the roads (Ministry of Infrastructure Secretariat of the National Road Safety Council, 2021). Road safety (RS) is one of the key priorities of the European Union's transport policy. As part of the "Vision Zero" strategy, Member States have adopted a long-term goal of completely eliminating fatalities and serious injuries in road accidents by 2050, with an intermediate goal of reducing the number of victims by 50% by 2030 (European Union, online-b).

In the last decade (2014–2023), significant progress has been made in the European Union countries, with the number of fatalities falling by about a quarter. At the same time, the rate of reduction varies significantly between countries. In Poland, there has been a marked improvement, but despite this progress, the fatality rate per million inhabitants remains higher than the EU average.

The issue of road safety (RS) has been widely analyzed in the literature. Pałęga (2017) identified the main risk factors in road traffic, while Wachnicka (2012) conducted a

spatial analysis of factors affecting RS at the provincial level. Rafalski (2012) focused on the role of heavy vehicles in shaping the level of safety on Polish roads. The causes of road accidents were also discussed in (Klepacki and Koper, 2018) while Gądek-Hawlena and Łoś (2018) analyzed dangerous behaviors of professional drivers and the effectiveness of technical solutions used in heavy goods vehicles.

General information on road safety can be found in monographs (Bąk-Gajda and Bąk, 2010;) and scientific publications (Orłowski and Wszeborski, 2020; Yannis and Papadimitriou, 2021).

The literature emphasizes that achieving the goals of Vision Zero requires a Safe System Approach, which takes into account the design of safe infrastructure, speed management, enforcement, and education of road users. The Vision Zero concept assumes that road safety is the shared responsibility of all participants in the system – road designers, public authorities, road users, vehicle manufacturers, and law enforcement agencies. In the event of an

accident, it is the designers and managers of the system who should take corrective and preventive measures (Srivastava and Shrivastava, 2023; Kim et al, 2017).

In many cities, such as New York and Toronto, Vision Zero is being implemented by interdepartmental teams combining the police, transport departments, public health services, and city authorities (Law and Petric, 2024). Scientific research conducted in these centers indicates the high effectiveness of the Vision Zero approach – for example, in Toronto, the importance of street lighting and pedestrian infrastructure quality has been demonstrated. In New York, a significant decrease in the number of accidents involving pedestrians was observed after the program was implemented (Sehtman-Shachar et al, 2024) and in Montgomery County, predictive models were developed to assess risk and recommend preventive measures (Kumfer et al, 2024). The issue under consideration has also been addressed by many authors (Zöldy, 2024; Ötvös, 2025; Dižo et al., 2025; Petrović et al., 2025; Kurhan et al., 2025; Stánicz and Török, 2026; Çeçen et al., 2026; Fischer et al., 2025a; Zöldy and Aijuan, 2025; Fischer, 2025; Ézsiás et al., 2024; Fischer et al., 2025b).

Local authorities, government agencies, and scientific communities are responsible for researching road accidents in the context of Vision Zero, collaborating within a common, systematic approach to road safety.

Despite numerous international studies, there are still few studies focusing on the quantitative assessment of Poland's progress in implementing Vision Zero in a comparative context with other EU countries. In addition, road accidents have significant socio-economic consequences, including losses in public health, medical costs, and lost productivity. Quantitative studies in Poland in a comparative context with the EU have been limited to date, which justifies the need for this analysis.

The aim of this study is therefore to analyze the dynamics of the number of fatalities in Poland compared to EU countries in 2014–2023, taking into account changes in the trend rate and key factors determining the effectiveness of road safety policy.

Research hypotheses:

- Hypothesis 1 (H_1): The implementation of the Vision Zero strategy in Poland between 2014 and 2023 contributed to a significant reduction in the number of road accident fatalities compared to the EU-27 average.
- Hypothesis 2 (H_2): The rate of decline in the number of fatalities in Poland is higher than the EU-27 average, which is due to the effectiveness of the

- synergy of infrastructure, educational, and control measures after 2019.
- Hypothesis 3 (H_3): The introduction of measures under the Safe System Approach, including infrastructure modernization and increased speed control, leads to a faster reduction in the fatality rate per 1 million inhabitants.
- Hypothesis 4 (H_4): Trends in the number of fatalities in the EU-27 show greater variability than in Poland, which is due, among other things, to differences in road safety policies, the effects of the COVID-19 pandemic, and the quality of statistical data.
- Hypothesis 5 (H_5): Despite significant progress in Poland, the level of road safety (number of fatalities per million inhabitants) remains lower than in countries with the highest EU standards, indicating a need for further action in the areas of infrastructure and traffic control.

2 Materials and Methods

The study was based on data on the number of fatalities in road accidents in Poland and European Union (EU-27) countries in 2014–2023 (European Union, [online-b]; Ministry of Infrastructure Secretariat of the National Road Safety Council, 2021). The average number of persons killed in road accidents between 2014 and 2023 is presented in Table 1. Fig. 1 shows the number of fatalities in European countries in 2023. The data for the EU and Poland come from official sources: National Road Safety Program 2021–2030 and Road safety statistics in the EU. These data are consistent with the definition of a fatality used in the EU (a person who died within 30 days of a road accident).

The time frame of 2014–2023 was chosen due to the full availability of data in a uniform format and methodological comparability between Member States. The data has been pre-cleaned and standardized—incomplete records have been removed, units of measurement and the presentation of values (number of victims, number of victims per 1 million inhabitants) have been standardized.

The study analyzed two basic variables:

- The number of fatalities – an absolute value representing the total number of people who died in road accidents in a given calendar year.
- The number of fatalities per 1 million inhabitants – a relative value that allows for a comparison of safety levels between countries with different populations.

This indicator was calculated using the Eq. (1):

$$R_t = \frac{D_t}{P_t} \times 10^6, \quad (1)$$

Table 1 Average number of persons killed in road accidents in 2014–2023 (European Union, online-b; European Union, online-a)

	Persons killed in road accidents	Persons killed in road accidents - rural roads	Persons killed in road accidents - urban roads	Persons killed in road accidents - motorway	People killed in road accidents per million inhabitants
European Union - 27 countries (from 2020)	22155.1	11622.4	8408.6	1834	49.9
Belgium	609.2	309.1	200.4	97	53.4
Bulgaria	607.7	357.9	202.5	47.3	89.9
Czechia	596.3	373.8	192.2	30.3	56.3
Denmark	172.5	104.1	54.1	14.3	29.7
Germany	3045.1	1760.7	922.2	362.2	37.1
Estonia	60.5	43.55556	16.22222	0	45.5
Ireland	156.9	104	43	7.333333	32
Greece	703	300.6667	360.4444	49.22222	65.5
Spain	1703.3	921.5	472.1	309.7	36.2
France	3212	1966.3	985.2	260.5	47.8
Croatia	298.6	100.2	171.3	27.1	74.2
Italy	3144.5	1501.2	1365.6	277.7	52.8
Cyprus	46.6	12.33333	31.44444	4.222222	53.2
Latvia	151.5	114.7143	44.28571	0	78.3
Lithuania	185	88.5	68.625	10.5	64.7
Luxembourg	29.8	19.5	6.1	4.2	49.7
Hungary	575	325.2	209.8	40	59.1
Malta	16.2	9.714286	7.428571	0	33.4
Netherlands	554.6	256.9	218.5	68.2	32
Austria	405.8	265.1	106.6	34.1	46.2
Poland	2629.3	1459.3	1109.3	60.7	69.8
Portugal	614.1	223.3	337.5	53.3	59.1
Romania	1790.7	627.7	1130.7	32.3	91.9
Slovenia	101.6	50.1	35.4	16.1	48.7
Slovakia	271.2	149.375	98.875	15.125	49.9
Finland	227.4	161.8	59.1	6.5	41.1
Sweden	246.7	163.1111	59.77778	19.22222	24.5
Iceland	11.2	8.2	3	0	32.2
Liechtenstein	1	0	0	0	26.5
Norway	112	88.4	23.3	0	21.1
Switzerland	226.6	115.3	91.9	19.4	26.7
United Kingdom	1842.6	1120.2	633.2	89.2	28.2
Serbia	520.4	241.6	241	37.8	76.2

where D_t denotes the number of fatalities and P_t denotes the population of the country in year t .

For the purposes of dynamic comparisons, all indicators are presented in the form of annual time series. A log-linear model was used to assess changes over time, allowing for the estimation of the average annual rate of change in the number of fatalities. The model takes the form of Eq. (2):

$$\ln(Y_t) = \alpha + \beta \times t + \varepsilon_t, \quad (2)$$

where:

- Y_t – number of fatalities in year t ,
- α – free term,
- β – directional coefficient determining the rate of change over time,
- ε_t – random component.

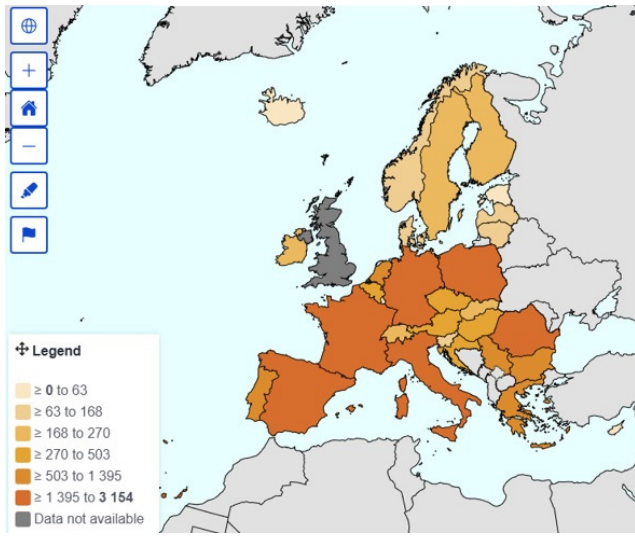


Fig. 1 Number of fatalities in European countries in 2023 (European Union, online-b)

Based on the value of the parameter β , the Annual Percent Change (APC) was calculated, i.e., the average annual percentage change in the number of fatalities, using the Eq. (3):

$$APC = (e^{\beta} - 1) \times 100\% . \quad (3)$$

Positive APC values indicate an increase in the number of victims, while negative values indicate a decrease. For each model, 95% confidence intervals (CI) were also determined using the standard deviation of the parameter β .

The model was fitted using the ordinary least squares (OLS) method in the Statsmodels package (Python). The goodness of fit was assessed based on the coefficient of determination R^2 and residual analysis.

Joinpoint analysis was used to identify significant changes in the trend rate. This technique allows the detection of points where there is a change in the direction or rate of decline/increase of the analyzed variable.

For each time series (EU and Poland, in numerical and relative terms), potential breakpoints were tested for the years 2015–2022. For each possible breakpoint location, two log-linear models were fitted – before and after a given year – and the sum of squares of residuals (RSS) was calculated. The breakpoint with the lowest RSS value was considered optimal.

Ultimately, based on a comparison of the variants, a breakpoint was detected in 2019 in each of the four cases analyzed, indicating a significant change in the dynamics of the number of victims during this period.

The log-linear model and joinpoint analysis were chosen because they allow for the precise determination of the average annual rate of change and points of significant

change in the trend in time series data on the number of fatalities. However, it should be noted that data may vary in quality and completeness between EU countries, which is a limitation of the study.

3 Results

The analysis was conducted for the years 2014–2023, covering a total of ten years of observation. The study took into account the number of fatalities in road accidents in Poland and in the European Union (EU-27) countries, as well as values converted to per 1 million inhabitants (Table 1).

During the period analyzed, the number of fatalities in the EU-27 countries decreased from 24,136 in 2014 to 20,380 in 2023, which corresponds to a total decrease of approximately 15.6%. In Poland, during the same period, the number of victims fell from 3,202 to 1,893, i.e. by 40.9%.

The relative values indicate that the number of fatalities per 1 million inhabitants decreased:

- in the EU from 55 to 46 (–16.4%),
- in Poland from 84 to 52 (–38.1%).

This indicates a faster rate of improvement in safety in Poland compared to the EU average, although the level of risk remains higher than in countries with the highest RS standards (e.g., Sweden, the Netherlands).

3.1 Log-linear trend analysis

A log-linear model described by the Eq. (4) was used to assess long-term trends:

$$\ln(Y_t) = \alpha + \beta \times t + \varepsilon_t , \quad (4)$$

where β represents the annual percentage change (APC).

The estimation results are presented in Table 2 and Fig. 2. The β coefficient in all models took negative values and was statistically significant ($p < 0.01$), confirming the overall downward trend in the number of fatalities.

- EU-27 (number of victims): APC = –2.54% per year (95% CI: –3.66%; –1.41%).
- Poland (number of victims): APC = –5.68% per year (95% CI: –7.30%; –4.04%).
- EU-27 (deaths per 1 million inhabitants): APC = –2.68% (95% CI: –3.81%; –1.54%).
- Poland (deaths per 1 million inhabitants): APC = –5.26% (95% CI: –6.80%; –3.69%).

The results of the log-linear model indicate that the rate of reduction in the number of fatalities in Poland was more than twice as high as the European Union average.

Table 2 Results of log-linear trend estimates for Poland and the EU-27 (2014–2023)

Variable	Data range	Slope (β)	APC [%]	95% CI for APC	Significance (p)	R^2	Trend interpretation
Number of fatalities – EU-27	2014–2023	−0.0257	−2.54	(−3.66; −1.41)	<0.01	0.71	Moderate decline in the number of victims
Number of fatalities – Poland	2014–2023	−0.0585	−5.68	(−7.30; −4.04)	<0.001	0.85	Strong downward trend
Deaths per 1 million inhabitants – EU-27	2014–2023	−0.0272	−2.68	(−3.81; −1.54)	<0.01	0.72	Moderate decline in the relative rate
Deaths per 1 million inhabitants – Poland	2014–2023	−0.0540	−5.26	(−6.80; −3.69)	<0.001	0.84	Faster decline in Poland than in the EU

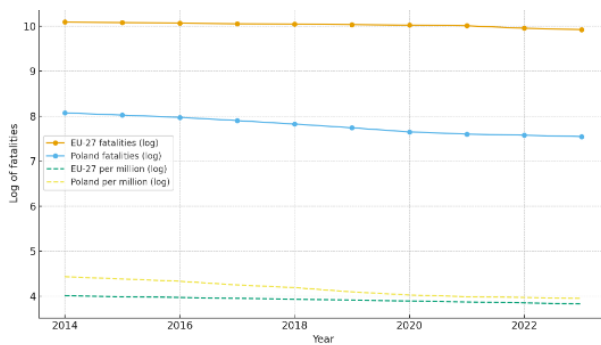


Fig. 2 Log-linear trends of road traffic fatalities in Poland and EU-27 (2014–2023)

In Poland, the average annual decline was 5.7%, while in the EU-27 it was 2.5%.

A similar relationship was observed for the number of deaths per 1 million inhabitants. In Poland, this indicator decreased by an average of 5.3% per year, and in the EU by 2.7%. High values of the coefficients of determination ($R^2 = 0.71$ – 0.85) confirm the good fit of the models to the empirical data.

The results suggest that Poland recorded a dynamic improvement in road safety during the period under review, confirming the effectiveness of the measures implemented after 2019 (including infrastructure modernization, increased enforcement of regulations, and educational activities). The average annual rate of decline in the number of fatalities in Poland was therefore more than twice as high as the average rate for the European Union as a whole, which indicates a progressive improvement in road safety in the country.

3.2 Joinpoint analysis

Joinpoint analysis was used to examine whether there were any significant changes in the trend rate during the period under review. This method allows the identification of the year in which the rate of change underwent a significant modification. The breakpoint analysis made it

possible to identify the year in which there was a significant change in the trend rate of fatalities.

For all four time series analyzed (EU and Poland, absolute and relative data), a breakpoint was detected in 2019, which means that there was a change in the dynamics of the number of victims during this period. The results are presented in Table 3 and Fig. 3.

- EU-27 (number of victims): before 2019, the annual trend was $APC = -1.25\%$, after 2019 $APC = +2.78\%$, which indicates a temporary reversal of the trend (probably related to 2020 and the impact of the COVID-19 pandemic on mobility).
- Poland (number of victims): before 2019, the annual trend was $APC = -1.77\%$, after 2019 -9.45% (95% CI: -13.45% ; -5.26%), which means a sharp acceleration in the decline in the number of victims after 2019.
- EU-27 (deaths per 1 million): before 2019 $APC = -1.60\%$, after 2019 $+2.99\%$.
- Poland (deaths per 1 million): before 2019 $APC = -1.64\%$, after 2019 -8.55% .

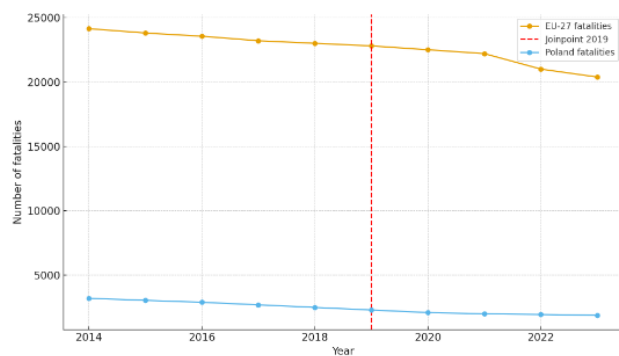
The results confirm that after 2019, there was a marked intensification in the decline in the number of fatalities in Poland, which can be linked to a combination of factors: traffic restrictions during the COVID-19 pandemic, an increase in the number of speed enforcement devices (speed cameras, sectional measurements), and improvements in road infrastructure.

Log-line and joinpoint trend graphs (Figs. 2 and 3) allow us to visually observe the acceleration in the decline in the number of victims in Poland after 2019 and the temporary reversal of the trend in the EU-27 during the same period. The graphs facilitate a quick understanding of the dynamics of change and confirm the results presented in Tables 2 and 3.

A comparison of the pace of change shows that although the level of safety in Poland is still lower than the EU average (52 victims per 1 million inhabitants compared to

Table 3 Joinpoint analysis results for Poland and the EU-27 (2014–2023)

Variable	Year of discontinuation	Analysis period	Slope (β)	APC [%]	95% CI for APC	Trend direction	Interpretation
Number of fatalities – EU-27	2019	2014–2019	−0.0125	−1.25	(−1.67; −0.83)	Moderate decline	Gradual improvement in safety
Number of fatalities – EU-27	2023	2019–2023	+0.0274	+2.78	(+0.56; +5.04)	Growth	Reversal of the trend after 2019 (COVID-19 effect and data volatility)
Number of fatalities – Poland	2019	2014–2019	−0.0177	−1.77	(−3.31; −0.20)	Weak decline	Slow reduction before 2019
Number of fatalities – Poland	2023	2019–2023	−0.0994	−9.45	(−13.45; −5.26)	Strong decline	Significant acceleration of the decline after 2019
Deaths per 1 million inhabitants – EU-27	2019	2014–2019	−0.0160	−1.60	(−1.91; −1.29)	Moderate decline	Stable reduction trend
Deaths per 1 million inhabitants – EU-27	2023	2019–2023	+0.0295	+2.99	(+0.79; +5.25)	Growth	Slowdown in decline after 2019
Deaths per 1 million inhabitants – Poland	2019	2014–2019	−0.0164	−1.64	(−3.22; −0.04)	Mild decline	Moderate improvement in safety
Deaths per 1 million inhabitants – Poland	2023	2019–2023	−0.0890	−8.55	(−13.13; −3.73)	Strong decline	Clear acceleration in reduction after 2019

**Fig 3** Joinpoint analysis of road traffic fatalities in Poland and EU-27 (2014–2023)

46 in the EU in 2023), the pace of improvement in Poland is faster. As a result, the gap between Poland and the EU average is steadily narrowing. In 2014, the Polish index was 29 points higher than the EU index, while in 2023 the difference fell to 6 points.

4 Discussion

The interpretation of the observed trends is grounded in the theoretical framework of the Vision Zero strategy and the Safe System Approach. According to this paradigm, road fatalities are not treated as random events, but as predictable and preventable outcomes of systemic failures in infrastructure design, speed management, vehicle safety, and institutional coordination. From this perspective, a sustained reduction in fatalities should result not from isolated interventions, but from coordinated actions addressing human vulnerability and kinetic energy in the transport system.

The empirical findings for Poland are consistent with the core assumptions of the Safe System Approach, particularly the emphasis on speed management and infrastructure that forgives human error. The stronger post-2019 decline in fatalities per million inhabitants suggests that interventions targeting systemic risk factors may yield measurable effects even in countries with historically higher baseline risk. At the same time, the observed variability across EU countries supports the Vision Zero assumption that outcomes depend not only on policy adoption, but on the intensity and coherence of implementation. A limitation of the study is the lack of direct exposure measures, such as traffic volume or vehicle-kilometers travelled, which prevents a full separation of structural safety improvements from pandemic-related mobility effects.

An analysis of data on the number of fatalities in road accidents in Poland and the EU-27 countries between 2014 and 2023 showed a significant improvement in road safety, with the rate of change in Poland being significantly higher than the EU average. The average annual decrease in the number of victims in Poland was 5.7% in absolute terms and 5.3% per 1 million inhabitants, which means that the country is steadily approaching the intermediate targets of Vision Zero set for 2030.

The improvement in safety in Poland after 2019 was due to the synergy of several factors: the modernization of road infrastructure, the introduction of new speed enforcement systems, and educational and social campaigns. The intensive efforts after this period can serve as a model for further strategies to reduce the number of victims.

The results of the joinpoint analysis indicate that in 2019 there was a significant acceleration in the decline in the number of victims in Poland, while in the EU-27 there were fluctuations in the trend, including a temporary reversal after 2019, most likely related to mobility restrictions during the COVID-19 pandemic. The intensification of the decline in Poland may be the result of the synergy of several factors, including:

- the implementation of modern infrastructure solutions (e.g., improvement of road quality, modernization of intersections, separation of pedestrian and bicycle traffic);
- increased control and enforcement of regulations (speed cameras, sectional speed measurements);
- educational programs and social campaigns to raise awareness among road users.

A critical interpretation of the sharp decline in road fatalities in Poland after 2019 (APC -9.45%) requires explicit consideration of the COVID-19 pandemic and its impact on traffic volumes. In 2020–2021, Poland experienced unprecedented reductions in mobility due to lockdowns, remote work, and restrictions on social and economic activity. According to Eurostat and national mobility data, road traffic volumes decreased markedly during this period, particularly in urban areas and long-distance travel.

This suggests that a substantial part of the observed post-2019 decline should be interpreted as a temporary exogenous shock, rather than solely as the structural effect of road safety policies. From this perspective, the years 2020–2021 may represent an anomalous deviation from the long-term trend, common across many EU countries.

However, an important observation is that in Poland the decline did not fully reverse after the gradual return of mobility levels in 2022–2023. Unlike the EU-27 average, which shows a temporary rebound in fatalities after 2019, Poland maintained a downward trend. This indicates that while the pandemic acted as a strong short-term accelerator, the persistence of lower fatality levels may also reflect structural improvements consistent with the Safe System Approach, including infrastructure modernization and intensified speed enforcement.

Therefore, the Polish case should not be interpreted as a simple "pandemic success", but rather as a combined effect, where COVID-19 amplified an already ongoing transformation of the road safety system. Future research incorporating traffic exposure indicators (e.g., vehicle-kilometers travelled) would allow a more precise decomposition of these effects.

The limitations of the study include: possible differences in accident reporting between EU countries, the impact of the pandemic on mobility, and the lack of detailed data on driver behavior and weather conditions at accident sites.

A comparison of safety levels in Poland and the EU shows that, despite a clear improvement, the number of victims per million inhabitants remains higher than the EU average (52 vs. 46 in 2023), which suggests that Poland still has the potential to further reduce risk, especially in rural areas and involving heavy vehicles. The results confirm the thesis that achieving the goals of "Vision Zero" requires a comprehensive and systematic approach in which infrastructure, regulatory, and educational measures are implemented in parallel.

Comparing the dynamics of change, it can be concluded that Poland, although starting from a higher risk level, has significantly reduced the gap with the EU average thanks to intensive measures taken after 2019 – from 29 points in 2014 to 6 points in 2023. Such a rapid pace of reduction in the number of victims is a positive sign of the effectiveness of road safety policy and confirms the possibility of achieving the intermediate goals of "Vision Zero" before 2030, provided that systemic measures are maintained and infrastructure and traffic surveillance continue to be developed.

At the same time, the analysis points to the need for further monitoring and research into factors affecting safety, including the role of driver behavior, weather conditions, road quality, and the involvement of heavy vehicles in accidents. Comparative studies between EU countries may also identify best practices that can be adapted in Poland to further accelerate progress.

International comparisons suggest that Poland could adapt proven solutions from countries with the highest road safety standards, such as Sweden and the Netherlands, including speed management, infrastructure design, and integration of activities between institutions.

5 Conclusions

Between 2014 and 2023, the number of fatalities in Poland decreased significantly – by 40.9% in absolute terms and by 38.1% per 1 million inhabitants. These results indicate a dynamic improvement in road safety in the country during the analyzed period.

The rate of decline in the number of victims in Poland (APC -5.68%) was more than twice as high as the EU-27 average (APC -2.54%), which proves the effectiveness of measures implemented after 2019, such as infrastructure

modernization, increased traffic surveillance, and educational campaigns.

The joinpoint analysis showed that in 2019 there was a significant acceleration in the decline in the number of victims in Poland, which was probably the result of the synergy of several factors, including reduced mobility during the COVID-19 pandemic, the development of speed surveillance systems, and improvements in the quality of roads and intersections.

Despite the noticeable improvement, the level of safety in Poland still remains lower than in countries with the highest road safety standards in the EU. In 2023, the number of fatalities per 1 million inhabitants in Poland was 52, while the EU average was 46, indicating the need for further action, especially in rural areas and in the context of heavy vehicle traffic.

A comparison with EU countries confirms the effectiveness of the systemic approach in the spirit of "Vision Zero" (Safe System Approach). The integration of infrastructure, regulatory, and educational measures contributes to a marked improvement in safety, and maintaining the current rate of reduction in the number of victims creates a real opportunity to achieve the intermediate goals of "Vision Zero" by 2030.

The results of this study have practical applications in the planning of transport and road safety policy in Poland, indicating specific areas requiring further action and monitoring.

The analysis confirms that the implementation of the Vision Zero strategy in Poland between 2014 and 2023 significantly reduced road traffic fatalities compared to the EU-27 average, supporting the first hypothesis (H_1). Poland experienced a 40.9% decline in absolute terms and a 38.1% decline per million inhabitants, demonstrating the effectiveness of safety measures.

The faster reduction rate in Poland than in the EU-27 (APC -5.68% vs. -2.54%) confirms the second hypothesis (H_2). Notably, the acceleration after 2019 (APC -9.45%) highlights the impact of infrastructure improvements, enhanced enforcement, and educational campaigns.

The third hypothesis (H_3) is also supported, as the Safe System Approach—including road modernization and speed control—led to a substantial decrease in fatalities per capita. In contrast, the EU-27 exhibited greater variability in trends, including a temporary increase after 2019 (APC $+2.78\%$), confirming hypothesis H_4 .

Finally, despite the progress, Poland's road safety level remains below that of the best-performing EU countries (52 vs. 46 deaths per million in 2023), confirming hypothesis H_5 and highlighting the need for continued systemic measures, particularly in rural areas and regarding heavy vehicle traffic.

Recommendations

1. Continue modernizing road infrastructure

The results of the analysis indicate that the improvement in safety in Poland was largely related to the modernization of roads, intersections, and the separation of pedestrian and bicycle traffic. It is recommended to continue investing in safe infrastructure, with particular emphasis on rural roads and sections with high accident rates.

2. Increased enforcement of traffic regulations

The significant acceleration in the decline in the number of victims after 2019 suggests the effectiveness of speed control and enforcement measures. The implementation of more speed cameras, sectional speed measurements, and monitoring systems in critical locations is recommended as a continuation of effective preventive measures.

3. Educational programs and social campaigns

Improving the awareness of road users was a factor that contributed to the reduction in the number of accidents. It is recommended to develop education for drivers, pedestrians, and cyclists, and to conduct social campaigns promoting safe behavior on the road.

4. Real-time data monitoring and analysis

In order to respond effectively to changes in accident dynamics, it is recommended to develop systems for collecting and analyzing data in real time. This will allow for faster identification of high-risk areas and implementation of preventive measures in accordance with the Safe System Approach principles.

5. Adaptation of best practices from EU countries

International comparisons show that Poland still lags behind the safety levels of countries with the highest RS standards. It is recommended to analyze and adapt proven solutions from countries such as Sweden, the Netherlands, and Denmark, including speed management, infrastructure design, and integration of activities between institutions.

6. Maintaining and strengthening the RS policy in the spirit of "Vision Zero"

Maintaining the current pace of safety improvement requires a consistent policy involving cooperation between public authorities, control services, road designers, and vehicle manufacturers. A systemic approach in the spirit of Vision Zero should remain the foundation for action in the coming years in order to achieve the intermediate targets by 2030 and the ultimate goal of eliminating fatalities by 2050.

7. Further research and evaluation of actions

It is recommended to systematically monitor the effectiveness of the implemented solutions and evaluate progress every 2–3 years in order to respond quickly to changes in accident dynamics in accordance with the principles of the Safe System Approach.

Symbols:

- H_1 - Hypothesis 1
- H_2 - Hypothesis 2
- H_3 - Hypothesis 3
- H_4 - Hypothesis 4

- H_5 - Hypothesis 5
- EU - European Union
- RS - Road safety
- APC - Annual Percent Change
- R_t - The number of fatalities per 1 million inhabitants
- D_t - denotes the number of fatalities in year t .
- P_t - denotes the population of the country in year t .
- Y_t - number of fatalities in year t ,
- α - free term,
- β - directional coefficient determining the rate of change over time,
- ε_t - random component.

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