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# ROAD TRANSPORT SAFETY IN POLAND AND COST INTENSITY OF NATIONAL LOGISTICS

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**Abstract:** The aim of this article is to assess the relationship between road transport safety and the cost intensity of domestic logistics in Poland in the years 2011-2023. The analysis is based on secondary data obtained from the Central Statistical Office. Domestic logistics performance is proxied by a cost intensity indicator defined as the share of total transport costs in gross domestic product (GDP). Road transport safety is measured by the number of road accidents per 100,000 population, while traffic intensity is included as a control variable measured in vehicle-kilometers.
The empirical analysis employs linear regression models estimated using the ordinary least squares method and is complemented by a descriptive analysis of trends in road accidents. Due to the presence of long-term trends and the limited number of observations, the baseline model estimated on levels is supplemented with a robustness check based on year-to-year changes (first-differences).
The results indicate that the relationship between road transport safety and logistics cost intensity depends on the model specification. While no statistically significant relationship is found in the level-based model, the first-difference specification reveals a positive and statistically significant association between changes in road accidents and changes in the share of transport costs in GDP. This suggests that a deterioration in road transport safety leads to higher logistics-related costs at the macroeconomic level. Traffic intensity is found to have a positive and statistically significant effect on logistics cost intensity in both model specifications. Overall, the findings indicate that improvements in road transport safety contribute to reducing transport costs and lowering the cost intensity of domestic logistics.
**Keywords:** road transport safety, logistics cost intensity, transport costs, traffic intensity, road accidents

## 1. INTRODUCTION

Transport plays a significant role in the modern economy, determining the efficiency of goods and passenger flows and the level of socio-economic development. At present, it faces numerous challenges (Kuras, 2024). The changes taking place in the transport sector are not only the result of technological progress, but also of the impact of global crises, events, and long-term development trends (Kozar & Matusiak, 2023). The transport services market is currently in a growth phase. The key determinants of road transport

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development include, above all, the growing demand for transport services and the intensification of international trade (Grondys et al., 2024). As a consequence, these developments lead to serious threats, such as a negative impact on the natural environment and a high accident rate (Janik and Chłąd, 2023), which in turn affects both the cost structure of national logistics systems and the conditions of their operation. Among the factors of key importance for the efficiency of transport systems, transport safety plays a special role. This concept refers to a system characteristic that enables it to operate under specific conditions without accidents or other undesirable events (Krystek et al., 2008). The literature emphasizes that safety, in particular road safety, should be treated as one of the fundamental conditions for the sustainable development of society in the context of ongoing globalization processes (Łukasik et al., 2013). At the same time, ensuring a high level of road transport safety is of key importance not only from a social but also from an economic perspective. This is because it affects the efficiency of the transport system, reduces the costs of accidents and disruptions in supply chains, and, as a result, the efficiency of logistics and the competitiveness of the national economy. For this reason, measures to improve transport safety are seen as part of economic and transport policy. They include both infrastructural and organizational solutions, as well as educational and informational activities.

Despite the growing interest in safety issues, relatively few studies in the literature focus on analyzing its impact on logistics efficiency, proxied by cost intensity indicators, in macroeconomic terms. In this study, logistics efficiency is operationalized inversely through transport cost intensity, defined as the share of transport costs in gross domestic product. Accordingly, the aim of this article is to assess the relationship between the level of road transport safety and the cost intensity of domestic logistics (interpreted as an inverse measure of efficiency) in the years 2011-2023. Based on the adopted objective, the following research question was formulated: to what extent do changes in the level of road transport safety affect the efficiency of domestic logistics in Poland? In order to empirically verify the research problem, the following research hypotheses were formulated. The main hypothesis assumes that an increase in the number of road accidents per 100,000 population leads to an increase in the share of transport costs in gross domestic product, which means a decrease in the efficiency of domestic logistics. In addition, a secondary hypothesis was formulated, according to which an increase in traffic intensity, measured by the number of vehicle-kilometers, leads to an increase in transport costs in relation to GDP.

## 2. METHODOLOGY OF RESEARCH

The aim of this article is to assess the relationship between the level of road transport safety and the cost intensity of domestic logistics in Poland. Based on this objective, the following research question was formulated: to what extent do changes in the level of road transport safety affect the cost burden of domestic logistics in Poland in the years 2011–2023? The analysis is based on annual data for Poland covering the period from 2011 to 2023. The adopted time horizon allows for the identification of long-term trends and limits the impact of short-term economic fluctuations.

The study is based on secondary data obtained from the public statistical database of the Central Statistical Office (Statistics Poland). As part of the research procedure, variables were selected to form the basis for the empirical analysis. Domestic logistics performance was measured using a cost intensity indicator defined as the share of total transport costs

in gross domestic product (GDP). Higher values of this indicator reflect a higher cost burden of transport in the economy and are interpreted as lower cost efficiency of domestic logistics.

The level of road transport safety was characterized using the number of road accidents per 100,000 population. Higher values of this variable indicate a deterioration of road safety conditions. In addition, in order to account for the scale and intensity of road transport, a single control variable was introduced to describe road traffic, measured as the number of vehicle-kilometers expressed in millions. This variable allows the impact of traffic intensity and road network congestion on transport costs to be controlled, independently of road safety conditions.

As a result, an econometric model in the form of a linear regression was specified to describe the relationship between road transport safety and the cost intensity of domestic logistics (1):

$$EFF_t = \beta_0 + \beta_1 SAFE_t + \beta_2 X_t + \varepsilon_t \quad (1)$$

where:

- $EFF_t$ - logistics cost intensity indicator in year t, defined as the share of total transport costs in gross domestic product,
- $\beta_0$ - intercept (constant term),
- $SAFE_t$ - road transport safety measure in year t, expressed as the number of road accidents per 100,000 population,
- $\beta_1$ - structural parameter capturing the impact of road transport safety on logistics cost intensity,
- $X_t$ - control variable capturing traffic intensity, measured in million vehicle-kilometers,
- $\beta_2$ - parameter determining the impact of traffic intensity on logistics cost intensity,
- $\varepsilon_t$ - random error term capturing the influence of other factors not explicitly included in the model.

The model was estimated using the ordinary least squares (OLS) method.

Based on the adopted research objective and econometric model specifications, the following research hypotheses were formulated:

**Main hypothesis (H1)**: an increase in the number of road accidents per 100,000 population leads to an increase in the share of total transport costs in gross domestic product, indicating a decrease in the efficiency of domestic logistics.

**Secondary hypothesis (H2)**: an increase in traffic intensity, measured by the number of vehicle-kilometers, leads to an increase in the share of transport costs in GDP.

In addition to estimating the linear regression model, the research procedure also included a descriptive analysis of the studied variables. In particular, time trend analysis and year-to-year dynamics were applied to identify the direction and scale of changes in the level of road transport safety during the analyzed period.

Given the limited number of annual observations and the presence of long-term trends in the analyzed variables, the baseline OLS model estimated on levels was complemented with a robustness check based on year-to-year changes (first-differences). Due to data availability, the analysis is based on annual observations. Therefore, the regression results should be interpreted as exploratory.

## 3. RESULTS

The empirical analysis was conducted in two stages. First, a descriptive analysis of changes in road transport safety in Poland was performed in order to identify long-term trends in the number of road accidents. Second, an econometric analysis was carried out to assess the relationship between road transport safety and the cost intensity of domestic logistics.

Fig. 1 presents the number of road accidents in Poland in the years 2011-2024.

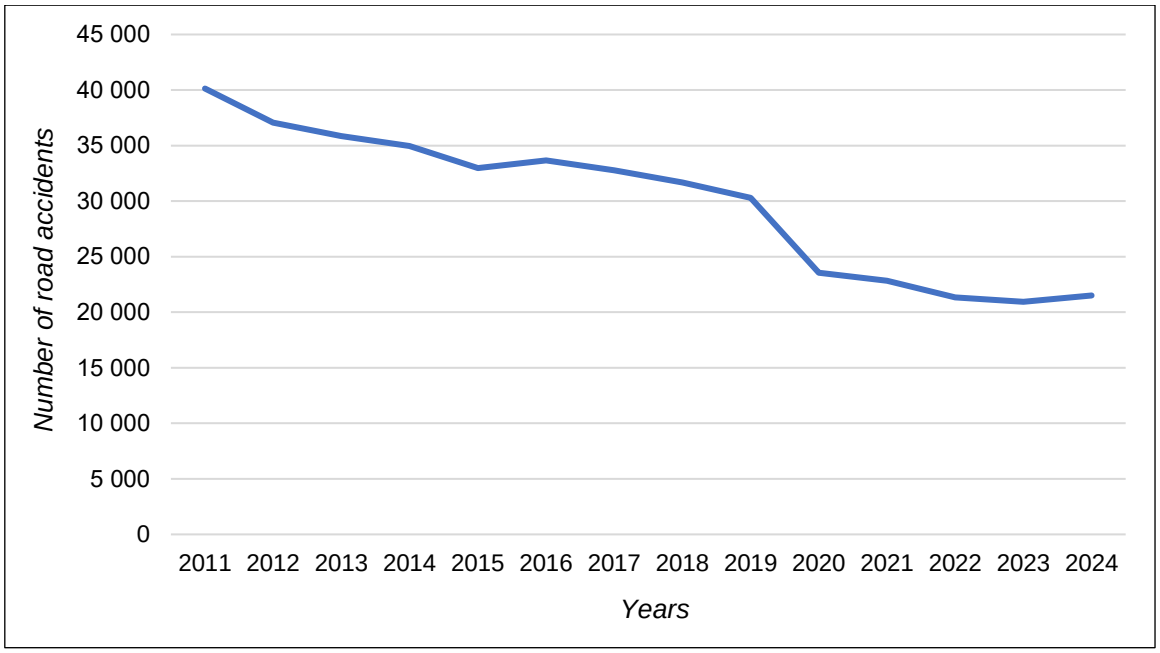



Fig. 1. Number of road accidents in Poland in 2011–2024

Source: Central Statistical Office. (2025). *Road accidents and their victims*. Local Data Bank. Available online: https://bdl.stat.gov.pl, updated: December 4, 2025.

The analysis indicates a clear downward trend in the number of road accidents over the analyzed period. In 2024, the number of road accidents was approximately 46% lower than in 2011, which reflects a long-term improvement in road transport safety. This trend suggests the effectiveness of safety-related measures implemented in Poland in recent years.

In order to further examine the dynamics of changes in road transport safety, year-to-year indices were analyzed (Fig. 2).

The dynamics of changes in the number of road accidents are presented using year-on-year dynamics indices (previous year = 100). In most of the years analyzed, the index value was lower than 100, indicating a decrease in the number of road accidents. Exceptions were observed in 2016 and 2024, when an increase in accidents was recorded. The largest decrease occurred in 2020, when the dynamics index reached 77.7%. This phenomenon was likely related to mobility restrictions during the COVID-19 pandemic. After 2021, the number of road accidents continued to decline, although the rate of reduction slowed significantly.

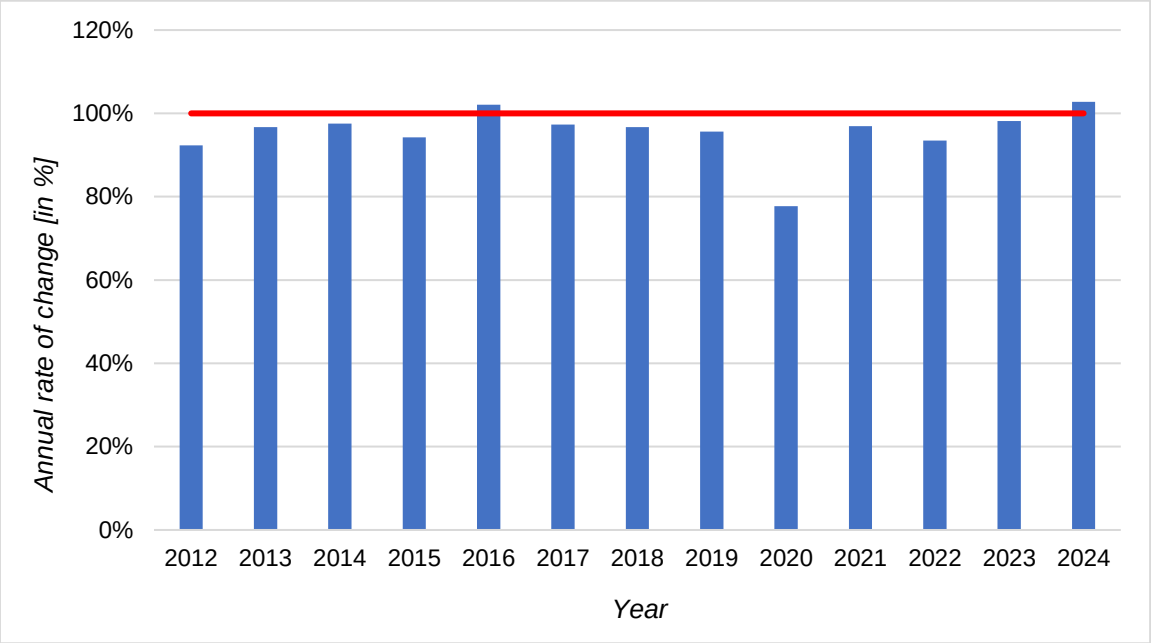



Fig. 2. Annual dynamics of changes in the number of road accidents in Poland in 2012-2024
Source: Central Statistical Office. (2025). *Road accidents and their victims*. Local Data Bank. Available online: https://bdl.stat.gov.pl, updated: December 4, 2025.

The descriptive analysis of road accidents indicates significant changes in the level of road transport safety during the period under review. The observed trends, in particular the long-term decline in the number of road accidents, provide a basis for further econometric analysis to assess the impact of road transport safety on the efficiency of domestic logistics. Fig. 1-2 include data up to 2024 for contextual purposes. However, the econometric analysis covers the period 2011-2023 due to data availability.
The econometric analysis was based on the estimation of linear regression models. As a baseline specification, an ordinary least squares (OLS) model estimated on levels was applied. The regression statistics for this baseline model indicate a very good fit to the empirical data (Table 1), although the limited number of observations requires cautious interpretation of the results.

Table 1
Regression statistics for the baseline econometric model

| *Statistic* | *Value* |
|---|---|
| Multiple R | 0.958062 |
| R squared | 0.917883 |
| Adjusted R squared | 0.901459 |
| Standard error | 0.001412 |
| Observations | 13 |

Source: own study based on data from the Central Statistical Office (Statistics Poland, GUS).

Table 2 presents the estimation results of the baseline model. The coefficient associated with the road traffic variable is positive and statistically significant, indicating that an increase in traffic intensity leads to an increase in the share of transport costs in GDP. In contrast, the coefficient for the road safety variable is negative and statistically insignificant

at conventional significance levels. This suggests that the relationship observed in the level-based specification may be influenced by long-term trends common to the analyzed variables.

Table 2
OLS estimation results (levels): *EFF = f(SAFE, TRAFFIC)*

| *Variable* | *Coefficient* | *Standard error* | *t-Stat* | *p-value* |
|---|---|---|---|---|
| Intercept | -0.0017 | 0.0014 | -1.18 | 0.267 |
| Number of road accidents per 100,000 population | -0.0004 | 0.0003 | -1.57 | 0.150 |
| Road traffic (million vehicle-kilometers) | 3.09E-07 | 1.11E-07 | 2.78 | 0.022 |

Source: own elaboration based on data from Statistics Poland, Local Data Bank.

Fig. 3 illustrates the bivariate relationship between the number of road accidents and logistics cost intensity in the level-based specification.

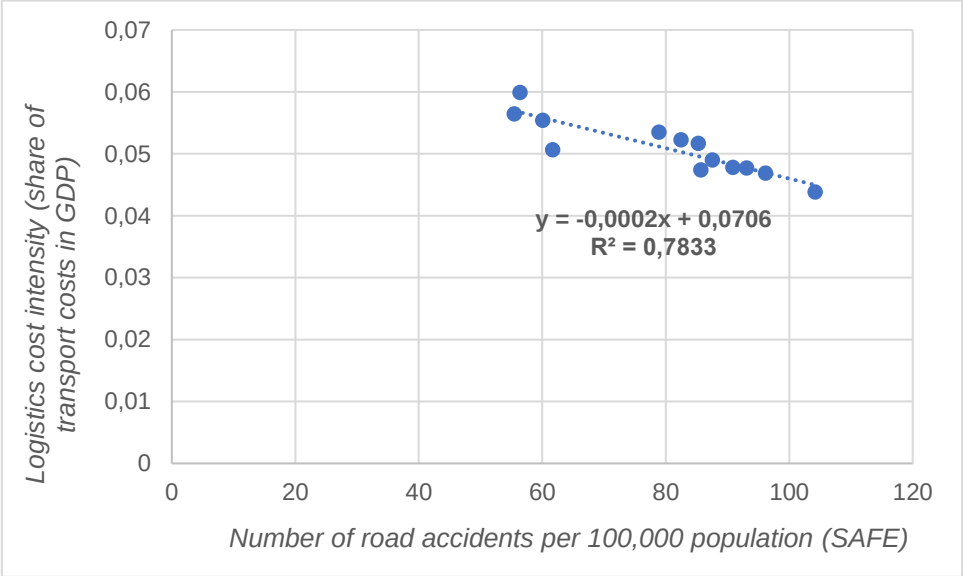



Fig. 3. Relationship between road transport safety and logistics cost intensity (levels)
Source: own elaboration based on data from Statistics Poland, Local Data Bank.

Overall, the baseline model estimated on levels indicates that the coefficient associated with the road accident variable is negative and not statistically significant at conventional levels. This further supports the interpretation that the relationship between road safety and logistics cost intensity in the level-based specification may be influenced by long-term trends in the analyzed variables.

To address this issue and assess the robustness of the results, an additional model based on year-to-year changes (first-differences) was estimated. This specification removes common time trends and allows the short-term relationship between changes in road transport safety and changes in logistics cost intensity to be examined. The results of the robustness check are presented in Table 3.

Table 3
Robustness check (first-differences): $\Delta EFF = f(\Delta SAFE, \Delta TRAFFIC)$

| Variable | Coefficient | Standard error | t-Stat | p-value |
|---|---|---|---|---|
| Intercept | -0.00003 | 0.0002 | -0.15 | 0.886 |
| Δ Number of road accidents per 100,000 population | 0.0005 | 0.0002 | 2.31 | 0.044 |
| Δ Road traffic (million vehicle-kilometers) | 2.41E-07 | 9.8E-08 | 2.46 | 0.035 |

*Note:* $\Delta X_t = X_t - X_{t-1}$
Source: own elaboration based on data from Statistics Poland, Local Data Bank.

To further illustrate the robustness check results, Fig. 4 presents the bivariate relationship between changes in the number of road accidents and changes in logistics cost intensity.

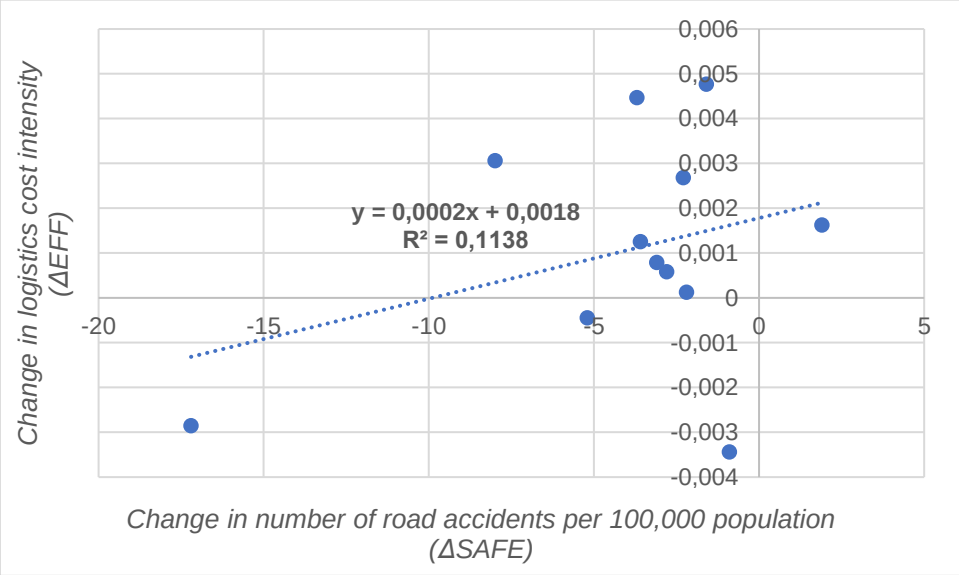



Fig. 4. Relationship between changes in road accidents and changes in logistics cost intensity (first-differences)
Source: own elaboration based on data from Statistics Poland, Local Data Bank.

In the differenced model, the coefficient for changes in the number of road accidents per 100,000 population is positive and statistically significant at the 5% level. This indicates that an increase in road accidents leads to an increase in the share of transport costs in GDP, confirming that a deterioration in road transport safety generates additional logistics costs at the macroeconomic level. This, in turn, translates into an increase in logistics cost intensity and, consequently, a decline in cost efficiency. The coefficient associated with changes in traffic intensity remains positive and statistically significant, which confirms the stability of this relationship across both model specifications.
The comparison of the baseline and differenced models suggests that the initial negative sign observed in the level-based specification was driven by common long-term trends in the data. After controlling for these trends, the robustness check provides results that are consistent with the research hypothesis and economic intuition. Therefore, the regression analysis should be interpreted as exploratory, with the differenced model offering stronger support for the identified relationship between road transport safety and the cost intensity

of domestic logistics. In contrast to the road safety variable, the coefficient associated with traffic intensity is positive and statistically significant in both the level-based model and the differenced specification. This indicates that an increase in the number of vehicle-kilometers consistently leads to a higher share of transport costs in GDP. Therefore, the secondary hypothesis (H2) is confirmed.

## 4. DISCUSSION

The aim of the article was to assess the impact of road transport safety on the cost intensity of domestic logistics in Poland in the years 2011-2023. The empirical analysis allowed the relationships between road safety, transport intensity, and logistics cost intensity (as a proxy for efficiency) to be examined from a macroeconomic perspective.

The results indicate that the relationship between road transport safety and logistics cost intensity depends on the model specification. In the baseline model estimated on levels, the coefficient associated with road accidents was negative and statistically insignificant, suggesting that the observed relationship may be influenced by common long-term trends in the analyzed variables. Therefore, the baseline results should be interpreted with caution and treated as exploratory.

After removing common trends through the use of a first-difference specification, the robustness check revealed a positive and statistically significant relationship between changes in the number of road accidents and changes in the share of transport costs in GDP. This confirms that a deterioration in road transport safety leads to an increase in logistics-related costs at the macroeconomic level. Consequently, improvements in road safety contribute to a reduction in transport costs and an increase in the efficiency of domestic logistics.

The obtained results are consistent with the literature on socio-economic appraisal of road safety measures, which emphasizes that the impacts of road transport safety extend beyond purely technical or accident-based indicators and translate into broader socio-economic and macroeconomic consequences. In this context, road safety improvements should be viewed not only as a social objective, but also as a factor shaping the cost burden and cost efficiency of national transport and logistics systems (Putatunda et al., 2025). Quantitative analyses of the socio-economic costs of road traffic crashes demonstrate the scale of this problem, showing that road traffic accidents generate substantial economic losses, often amounting to several percent of GDP (Bougna et al., 2022). Additional evidence from cost-of-crash studies supports the macroeconomic relevance of road transport safety. For example, a comprehensive assessment for Kazakhstan estimated that the socio-economic costs of road traffic accidents amounted to approximately 3.3% of GDP, indicating that insufficient road safety can generate substantial economic losses at the national level (Wijnen, 2021).

The identified relationship can be explained by a reduction in losses associated with delivery delays, disruptions in supply chains, infrastructure damage, and insurance and operating costs. These findings are consistent with the results reported by Kozłowski, Adamek, Palczewska (2016), who demonstrated that each road collision generates additional costs for transport companies, while a reduction in the number of such events leads to lower operating costs.

A statistically significant impact was also identified for the control variable describing traffic intensity. An increase in the number of vehicle-kilometers leads to an increase in the share of transport costs in GDP, indicating a higher burden on the road network and additional

transport operating costs. This result is consistent with theoretical assumptions (Kozerska, 2021) and confirms the importance of traffic management and infrastructure development for improving both the safety and efficiency of transport systems (Tumielewicz and Szmelcuch, 2025). As emphasized by Chłąd (2024), such measures are also crucial for optimizing transport costs in the operations of Polish companies.
Overall, the findings are consistent with the conclusions presented in the literature (e.g., Sroka, 2022; Jaździk-Osmólska, 2022; Foryś and Płocki, 2022), which highlight both the social and economic consequences of insufficient road transport safety.

## 5. CONCLUSION

The aim of the article was to assess the impact of road transport safety on the cost intensity of domestic logistics in Poland in the years 2011-2023. The research addressed the question of whether changes in the level of road transport safety affect the share of transport costs in gross domestic product, thereby influencing the cost efficiency of domestic logistics.
The empirical analysis indicates that the relationship between road transport safety and logistics cost intensity depends on the model specification. In the baseline model estimated on levels, the impact of road accidents on logistics cost intensity was not statistically significant, which suggests that this relationship may be influenced by long-term trends present in the data. Therefore, the baseline results should be interpreted with caution and treated as exploratory.
After controlling for common time trends by applying a first-difference specification, the robustness check revealed a positive and statistically significant relationship between changes in the number of road accidents and changes in the share of transport costs in GDP. This finding supports the main research hypothesis (H1) and indicates that a deterioration in road transport safety leads to an increase in logistics-related costs at the macroeconomic level. Consequently, improvements in road transport safety contribute to reducing transport costs, enhancing the cost efficiency of domestic logistics, and lowering the macroeconomic burden of transport costs. This interpretation is consistent with cost-of-crash evidence indicating that road traffic crashes can generate macroeconomic losses amounting to several percent of GDP (Taniform et al., 2023).
The analysis also confirmed the importance of traffic intensity as a factor affecting logistics cost intensity. An increase in the number of vehicle-kilometers was found to be associated with higher transport costs relative to GDP, which highlights the role of traffic management and infrastructure capacity in shaping the efficiency of transport systems. The secondary hypothesis (H2) was confirmed in both model specifications, indicating that increased traffic intensity constitutes a stable and significant determinant of logistics cost intensity.
Overall, the results suggest that road transport safety is an important determinant of the cost efficiency of domestic logistics. Although the study is limited by the use of annual data and a relatively small number of observations, the findings provide valuable insights into the economic consequences of road safety and may serve as a basis for future research using longer time horizons or higher-frequency data. From a policy perspective, the results support the inclusion of road safety improvements as an integral element of transport and logistics policy in Poland.

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