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BENCHMARKING ROAD SAFETY PERFORMANCE IN THE EU PROJECT ROADS4ALL USE CASE COUNTRIES: Insights from the International Road Federation Road Safety Dataset/IRF Data Warehouse

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Abstract: Reliable road safety data are essential for evidence-based policymaking and for supporting the implementation of the Safe System Approach. While road safety performance has improved across Europe in recent years, substantial differences persist between countries in terms of fatality outcomes, Vulnerable Road User (VRU) risks, infrastructure characteristics and transport exposure. This paper provides a comparative assessment of road safety performance in the five Roads4All (101203314) Use Case countries—Estonia, Greece, Croatia, Serbia and Italy—using indicators from the International Road Federation (IRF) World Road Statistics for the period 2018–2023. The analysis considers population-based fatality rates, temporal trends, VRU fatalities, road-network characteristics, vehicle ownership and selected traffic-exposure indicators. Descriptive statistical analysis and cross-country benchmarking are applied to identify common trends, persistent challenges and areas for targeted intervention.

The results reveal considerable heterogeneity in the evolution and underlying characteristics of road safety performance across the five countries. Using the 2019 pre-pandemic baseline adopted in the EU road safety framework, published 2023 figures indicate reductions in the number of road deaths of approximately 10% in Greece, 8% in Croatia, 6% in Serbia and 2% in Italy, while Estonia recorded an increase of approximately 13%. Differences in transport exposure and infrastructure development nevertheless demonstrate the importance of interpreting fatality outcomes within their broader system context. Across 2018–2023, the reported road network increased by approximately 52% in Estonia and 4% in Serbia, remained broadly stable in Italy and Greece, and declined slightly in Croatia. Motorway and highway provision increased across all five countries, while vehicle ownership also increased, particularly in Serbia, Croatia and Greece. These developments illustrate the importance of considering network scale, infrastructure characteristics and motorisation when comparing national road safety performance.

The analysis of VRU fatalities further demonstrates substantial differences between countries and road user groups. Pedestrian fatalities declined markedly in Greece, Croatia and Italy, while Serbia recorded a more moderate reduction and Estonia recorded an increase. In contrast, fatalities among users of motorised two- and three-wheeled vehicles increased in Italy, Greece and Croatia over the longest comparable periods available, while declining in Serbia. Cyclist fatalities also followed divergent trajectories, increasing in Italy, Serbia and Estonia but declining in Croatia and Greece. These findings demonstrate that improvements in aggregate road safety performance do not necessarily translate into equivalent improvements for all road user groups, highlighting the need for targeted, risk-based interventions.

Building on the longitudinal and multidimensional assessment, the paper proposes an exploratory four-tier benchmarking framework, ranging from emerging to leading performance, based on comparative fatality outcomes and vehicle-, infrastructure- and exposure-related indicators across the 2018–2023 period. The framework is not intended to establish an absolute ranking of countries, but rather to facilitate structured peer comparison, knowledge exchange and the prioritisation of evidence-based interventions and

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infrastructure investments. The paper demonstrates the value of harmonised international road safety indicators as a strategic evidence base for assessing road safety performance, supporting infrastructure-readiness assessments and informing risk-based investment decisions. Ultimately, the findings highlight the importance of tailored, data-driven and system-based approaches to road safety and demonstrate how internationally comparable datasets can support progress towards Vision Zero and the objectives of the EU Road Safety Policy Framework 2021–2030.

Keywords: Road safety indicators, Safe System, Road safety management, Benchmarking, Vision Zero

1. INTRODUCTION

Road safety remains a major challenge for transport systems worldwide and, although substantial progress has been achieved across Europe, road crashes continue to result in significant numbers of fatalities and serious injuries. The World Health Organization estimates that approximately 1.16 million people die each year as a result of road traffic crashes globally, with vulnerable road users accounting for more than half of all road traffic deaths. The Safe System Approach has consequently become an ever more important framework for road safety policy, recognising that human error is inevitable and transport systems should be designed and managed so that errors result in neither death nor serious injury (WHO, 2026).

The European Union has adopted the objective of reducing road deaths and serious injuries by 50% by 2030 compared with 2019 levels, whilst working towards the longer-term objective of Vision Zero. However, progress towards these objectives remains uneven. In 2023, approximately 20,400 people were killed in road crashes across the EU, representing only a 1% reduction compared with 2022 and a 10% reduction compared with 2019 (EC, 2023). The European Commission has highlighted considerable differences between Member States, with some countries progressing towards the 2030 target while others experienced stagnation or increases in fatalities.

These differences are particularly relevant when considering the relationship between road safety outcomes and the characteristics of transport systems. Fatality rates are influenced not only by road-user behaviour but also by road infrastructure, vehicle safety, traffic exposure, speed management, emergency response, enforcement, and the institutional capacity of road safety management systems. Consequently, absolute numbers of fatalities provide only a partial picture of road safety performance and comparative indicators that account for population, vehicle fleets, traffic exposure and infrastructure are required to better understand differences between countries.

This paper focuses on the five countries participating as part of the EU project Roads4All Use Cases: Estonia, Greece, Croatia, Serbia and Italy. These countries represent diverse geographical, demographic and transport-system contexts and display varying road safety performance profiles. Using the International Road Federation (IRF) Road Safety Dataset, this paper investigates the evolution of selected road safety indicators between 2018 and 2023 and explores how harmonised indicators can be used to support cross-country benchmarking.

The paper addresses three research questions:

1. How has road safety performance evolved across the five Roads4All Use Case countries between 2018 and 2023?
2. What differences and common patterns can be identified using population-, vehicle- and infrastructure-related indicators?
3. How can harmonised indicators support an exploratory benchmarking framework for peer comparison and prioritising road safety interventions?

2. BACKGROUND AND CONCEPTUAL FRAMEWORK

2.1. From fatality reduction to Safe System performance

Traditional road safety policies have often focused on reducing crash frequency through measures targeting road-user behaviour, enforcement and awareness. The Safe System Approach broadens this perspective by considering the road transport system as an integrated system involving people, vehicles, infrastructure and institutional processes. Its fundamental premise is that humans are fallible and that the transport system must therefore be sufficiently forgiving to prevent foreseeable errors from resulting in fatal or serious outcomes (WHO, 2026).

Infrastructure is particularly important within this framework. Safe road design, appropriate speed management, separation of conflicting road users, safe intersections, adequate road markings and signage, and appropriate roadside protection can reduce both the probability and severity of crashes. The Safe System therefore shifts the focus from assigning responsibility exclusively to individual road users towards shared responsibility among road authorities, infrastructure operators, vehicle manufacturers, policymakers and users.

This perspective is also relevant to the Roads4All project, where safer and more resilient road infrastructure is considered in conjunction with wider developments in transport and mobility. Quantitative road safety indicators can provide a baseline for identifying areas where infrastructure and system-level interventions may have the greatest potential impact.

2.2. The importance of benchmarking

Cross-country benchmarking can support road safety management by providing a structured basis for identifying differences in performance. However, benchmarking must be undertaken carefully. Countries differ in population density, urbanisation, road network length, traffic volumes, vehicle ownership, modal split, geography and climatic conditions. A single indicator can therefore be misleading when used in isolation.

For example, fatalities per 100,000 inhabitants provide a useful measure of population-level risk, but they do not account for differences in mobility exposure. Similarly, fatalities per vehicle can provide a different perspective on risk associated with motorisation, while fatalities per kilometre of road network can provide insight into the relationship between fatalities and infrastructure extent. A multidimensional indicator approach is consequently more appropriate for comparative assessment.

The IRF World Road Statistics provide an important basis for such analysis. The IRF has collected road transport statistics for more than six decades and its current dataset covers more than 200 countries and over 200 indicators. Data are collected through a network of primary statistical sources and undergo verification and validation before publication (IRF, 2025). The resulting dataset includes indicators covering road networks, vehicle fleets, traffic, accidents, infrastructure and other dimensions of transport systems.

3. DATA & METHODOLOGY

3.1 Dataset and geographical scope

The analysis uses the IRF World Road Statistics (WRS) 2025 edition, covering the period 2018–2023. The five countries included in the assessment are Estonia, Greece, Croatia, Serbia and Italy. These countries constitute the Roads4All Use Case countries considered in this

analysis. The selection of indicators was guided by three principles: comparability across countries, relevance to road safety performance, and availability over time. The core indicators considered are:

- total road fatalities;
- fatalities per 100,000 inhabitants;
- fatalities per million inhabitants;
- vulnerable road user fatalities, where available;
- total road network length, road network density and motorway/highway provision;
- four-wheeled vehicles per 1,000 inhabitants and per kilometre of road; and
- passenger-car vehicle-kilometres, where available.

Fatality rates per population are calculated as such:

$$\text{Fatality rate} = \text{road fatalities} / \text{population} \times 100{,}000 \quad (1)$$

Equivalent rates per million inhabitants are used where comparison with European Commission statistics is appropriate. Data availability is not uniform across countries and indicators. Where a complete 2018–2023 series is unavailable, the longest comparable period is reported and its start year stated.

3.2 Longitudinal analysis

The period 2018–2023 was selected to capture both the pre-pandemic situation and subsequent developments. The inclusion of 2020 and 2021 is particularly important because changes in mobility during the COVID-19 pandemic affected traffic volumes and road safety outcomes in many countries. Consequently, changes in absolute fatalities during these years should not automatically be interpreted as evidence of structural improvements in road safety. The analysis therefore focuses primarily on longer-term trends and compares 2023 outcomes with the pre-pandemic baseline. This approach is consistent with the EU road safety framework, which uses 2019 as the baseline year for its 2030 target (EC, 2023).

3.3 Exploratory benchmarking classification

To translate the results into a practical decision-support framework, an exploratory four-tier classification is proposed using the comparative fatality outcomes and vehicle-, infrastructure- and exposure-related indicators described above and the indicator value range is taken from fatalities per 100,000 population graph (see below).

The tiers structure peer comparison rather than constitute a validated composite index; assignments are therefore provisional pending agreement on explicit decision rules or thresholds:

Tier 1 – Emerging performer: comparatively high fatality levels and limited improvement over time.

Tier 2 – Developing performer: evidence of improvement, but with persistent gaps in one or more key indicators.

Tier 3 – Advanced performer: comparatively favourable fatality outcomes combined with sustained improvement and relatively strong performance across several indicators.

Tier 4 – Leading performer: consistently strong performance across population-, vehicle- and infrastructure-related indicators, combined with sustained progress towards long-term safety objectives.

The classification is intended as an exploratory benchmarking tool rather than an absolute ranking or judgement on the effectiveness of a country's entire road safety system.

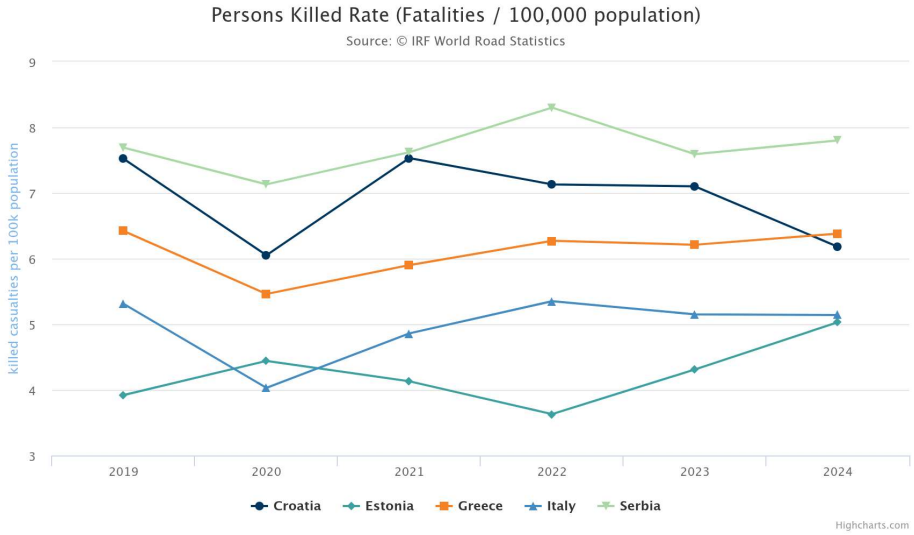


Fig. 1. Persons killed rate (Fatalities / 100 000 population). Source: IRF World Road Statistics

Table 1. Provisional exploratory benchmarking profiles for Roads4All countries

Country	VRU profile and risk context	Provisional overall profile
Croatia	High PTW involvement; pedestrian fatalities –31%; cyclist fatalities –18%	Tier 3 – Advanced
Estonia	Moderate: increase in pedestrian and cyclist fatalities but very low PTW fatalities	Tier 3 – Advanced
Italy	High PTW/VRU involvement; pedestrian fatalities –21%; PTW fatalities increased	Tier 2 – Developing
Greece	High PTW involvement; pedestrian fatalities –30%; cyclist fatalities –17%	Tier 2 – Developing
Serbia	High road-risk context; PTW fatalities –16%, but cyclist fatalities +21%	Tier 1 – Emerging

3.4 Proposed four-tier benchmarking framework

Based on the results, the proposed exploratory classification can be used to structure future analysis of road safety performance. Building on the longitudinal and multidimensional assessment, the paper sets out a four-tier framework, ranging from emerging to leading performance, based on comparative fatality outcomes and vehicle-, infrastructure- and exposure-related indicators across the 2018–2023 period. The framework should be treated as provisional until explicit tier-assignment rules are agreed.

Table 2. Tier system for exploratory benchmarking purposes

Tier	Performance profile	Typical characteristics
Tier 1	Emerging performer	High fatality rates, limited progress and persistent infrastructure and exposure challenges
Tier 2	Developing performer	Evidence of improvement but substantial gaps remain
Tier 3	Advanced performer	Relatively low fatality rates and sustained improvements across several indicators
Tier 4	Leading performer	Strong performance across multiple indicators and sustained progress towards Vision Zero

The principal advantage of this approach is that it avoids presenting road safety as a single-dimensional ranking. A country can perform well in terms of population-based fatalities while facing significant challenges regarding vulnerable road users or infrastructure. The classification should therefore be accompanied by an indicator profile rather than used as a standalone score. For Roads4All, this approach can facilitate peer learning. Countries with similar performance profiles can exchange experiences regarding successful infrastructure measures, governance arrangements, data systems and investment strategies. Countries with different profiles can use the framework to identify specific areas where targeted interventions may be appropriate.

4. RESULTS

4.1 Overall differences in road fatality rates

Estonia combines a comparatively low 2023 population-based fatality rate with an increase in the number of road deaths compared with the 2019 baseline. Pedestrian and cyclist fatalities increased over the study period, while powered two-wheeler (PTW) fatalities remained very low; the substantial expansion of the reported road network (+51.6%) and passenger-car vehicle-kilometres (+12.4%) also affects interpretation. Greece recorded a comparatively high 2023 fatality rate but fewer road deaths than in 2019; PTW fatalities increased, while pedestrian and cyclist fatalities declined. Croatia similarly combined a comparatively high fatality rate with improvement in the number of road deaths compared with 2019, alongside increased PTW fatalities and reductions in pedestrian and cyclist fatalities. Serbia recorded a comparatively high fatality rate but a reduction in road deaths compared with 2019, together with rapid growth in motorisation (+26.9%) and motorway/highway provision (+23.1%); PTW fatalities declined while cyclist fatalities increased. Italy recorded a lower 2023 fatality rate than Greece, Croatia and Serbia but comparatively limited improvement in road deaths relative to 2019. Its VRU profile was mixed, with lower pedestrian fatalities and higher PTW fatalities over the available series, while the country also had the largest road network and the highest motorisation level among the five countries. These profiles should be interpreted as exploratory rather than as a definitive ranking.

The analysis identifies persistent differences in road safety performance across the five countries. During the 2018–2023 period, population-based fatality rates remained within a range of approximately 4 to more than 7 fatalities per 100,000 inhabitants. This indicates substantial differences in population-level road safety risk despite the countries sharing common European road safety objectives. The most recent comparable European data confirm the broad pattern observed in the IRF dataset. In 2023, Estonia recorded approximately 43 road deaths per million inhabitants, equivalent to 4.3 deaths per 100,000 inhabitants. Greece recorded approximately 60 per million, or 6.0 per 100,000, while Croatia recorded approximately 71 per million, corresponding to 7.1 per 100,000. Italy recorded approximately 52 deaths per million, or 5.2 per 100,000. For Serbia, preliminary 2023 data indicate approximately 74 deaths per million inhabitants, equivalent to 7.4 per 100,000 (EC, 2023a; EC, 2023b).

These figures illustrate the importance of benchmarking beyond absolute fatalities. Italy, for example, has a substantially larger population and consequently a much higher absolute number of fatalities than Estonia or Croatia. However, its population-adjusted fatality rate is lower than that of Croatia and Serbia. Conversely, Estonia has a relatively small absolute number of fatalities but its rate remains sensitive to annual fluctuations because of its smaller population. The European Commission's 2023 data similarly demonstrate substantial differences among EU Member States. The EU average was approximately 46 deaths per million inhabitants, compared

with 43 in Estonia, 60 in Greece, 71 in Croatia and 52 in Italy (EC, 2023a). Serbia's 2023 rate of approximately 74 deaths per million was higher than the EU average (EC, 2023b).

4.2 Evolution over time

Referring to Figure 1, the longitudinal analysis shows that the five countries do not follow a uniform trajectory. Greece, Croatia and Italy show evidence of improvement compared with the pre-pandemic baseline, although the scale of progress differs considerably. Preliminary European Commission data indicate that, between 2019 and 2023, the number of road deaths declined by approximately 10% in Greece, 8% in Croatia and 2% in Italy. Transport Community data indicate a reduction of approximately 6% in Serbia over the same period (EC, 2023a; EC, 2023b). These figures demonstrate that a downward trend alone does not necessarily indicate that a country is progressing sufficiently towards the 2030 target.

Estonia presents a particularly interesting case. Its population-based fatality rate was relatively low compared with the other Roads4All countries during parts of the assessment period, but the 2023 rate increased compared with 2022. Preliminary European Commission data show that the number of road deaths in 2023 was approximately 13% higher than in 2019 (EC, 2023a). This highlights the importance of analysing multiple years rather than using a single year's result to characterise national performance. The results also demonstrate the need to account for pandemic-related changes. Fatality rates declined sharply in several countries in 2020 as mobility and traffic volumes were disrupted. Subsequent increases should therefore not necessarily be interpreted as deterioration in safety management. A robust benchmarking approach should distinguish between temporary mobility effects and structural changes in road safety performance.

4.3 Vulnerable Road Users

The analysis of vulnerable road users provides further insight into the differences in road safety performance across the five Roads4All Use Case countries. While overall fatality rates provide an important measure of road safety outcomes, examining specific road user groups helps identify which categories of road users remain particularly exposed to fatal crashes. The International Road Federation dataset distinguishes between pedestrians, pedal cycle users, and users of motorised two- or three-wheeled vehicles, allowing the evolution of these groups to be assessed between 2018 and 2023.

Pedestrians represent one of the most significant vulnerable road user groups across the countries analysed. Italy recorded a reduction of approximately 21% in pedestrian fatalities between 2018 and 2023. Greece and Croatia recorded even larger reductions of approximately 30% and 31%, respectively, while Serbia experienced a more moderate decline of around 10%. Estonia, in contrast, recorded an increase of approximately 50%. These results highlight that improvements in overall road safety do not necessarily translate uniformly across vulnerable road user groups.

Fatalities among users of motorised two- or three-wheeled vehicles show a different pattern. Italy recorded consistently high numbers, increasing by 24% from 2018 to 2023, the longest comparable period available in the series used here. Greece similarly reported high levels, increasing by 14% over the reported 2018–2023 series, while Croatia increased by 29% over the same period. Serbia, by contrast, reduced fatalities by 16% between 2018 and 2023, while Estonia remained relatively stable with minimal fatalities. The comparatively high figures observed in Italy and Greece indicate the importance of motorised two- and three-wheeled

vehicles as a specific road safety challenge, particularly in countries where these modes constitute an important component of everyday mobility.

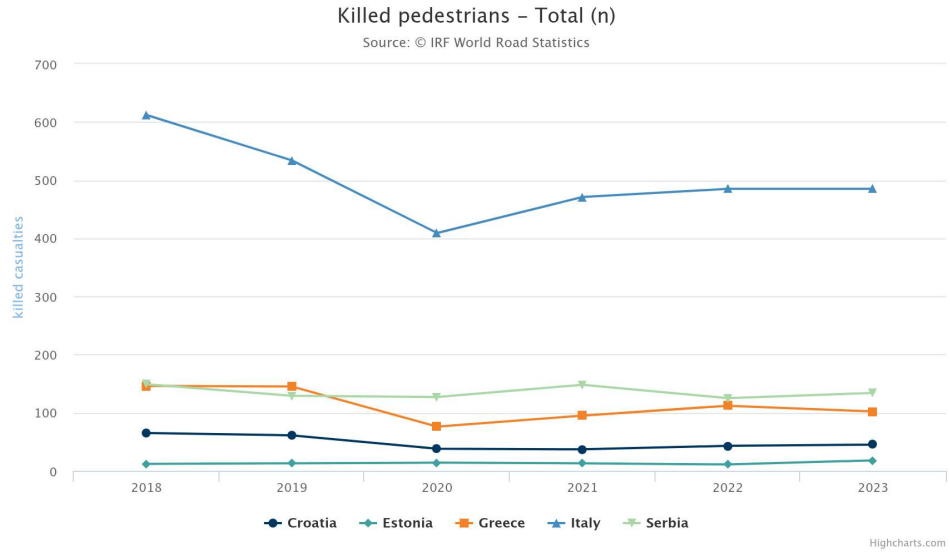


Fig. 2. Pedestrian fatalities (2018–2023). Source: IRF World Road Statistics

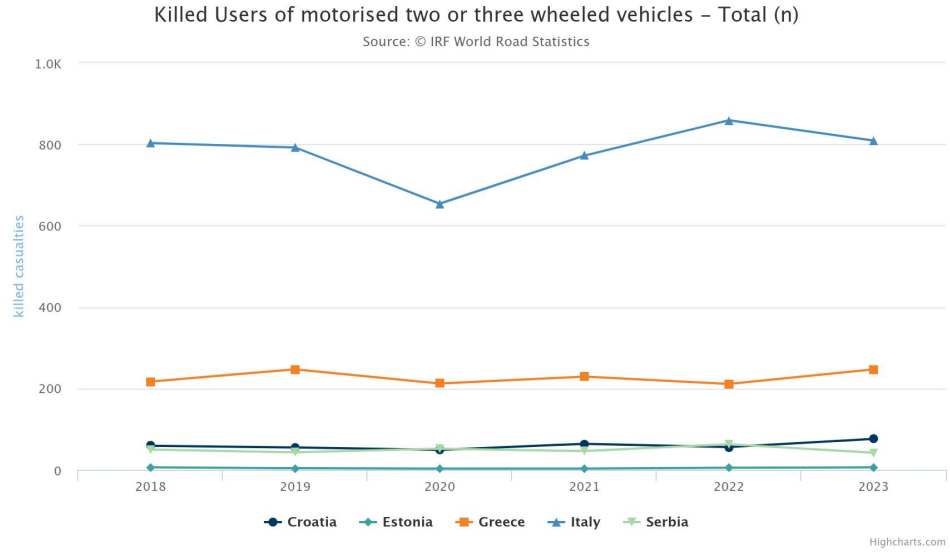


Fig. 3. Killed users of motorised two- or three-wheeled vehicles (2018–2023). Source: IRF World Road Statistics

Pedal cycle fatalities are considerably lower in absolute terms but display notable differences in their temporal evolution. Italy recorded the highest number of cyclist fatalities in every year, increasing slightly, by 6%. Serbia also experienced an increase, by 21%, while Estonia increased

by 67%, however given the small number of fatalities in Estonia, this relative increase should be interpreted with caution. Croatia and Greece, in contrast, recorded reductions over the same period, by 18% and 17% respectively. Given the relatively small absolute numbers in some countries, year-to-year variations should be interpreted cautiously; nevertheless, the persistence of cyclist fatalities demonstrates that improvements in overall road safety performance do not necessarily affect all vulnerable road user groups equally.

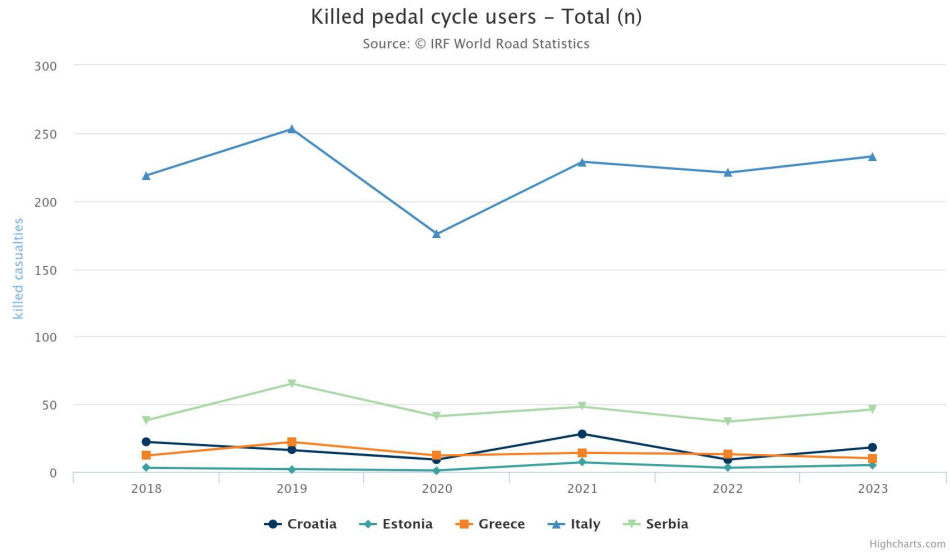


Fig. 4. Killed pedal cycle users (2018–2023): Source: IRF World Road Statistics

Overall, the results reveal substantial variation in the evolution of vulnerable road user fatalities across the five countries. Pedestrian fatalities generally show a declining trend, particularly in Croatia, Greece and Italy, whereas fatalities involving motorised two- or three-wheeled vehicles remain comparatively high and, in several countries, have increased since 2018. Cycling fatalities show a more heterogeneous pattern, with increases in Italy, Serbia and Estonia but decreases in Croatia and Greece. These findings reinforce the importance of disaggregating road safety outcomes by road user type when benchmarking national performance. They also suggest that targeted interventions addressing pedestrian protection, safer cycling environments, and the risks associated with motorised two- and three-wheeled vehicles should complement broader road safety measures under the Safe System approach.

4.4 Infrastructure and exposure indicators

Infrastructure characteristics and traffic exposure provide important contextual information for interpreting differences in road safety performance across the five Roads4All Use Case countries. The indicators considered include total road network length, road network density, motorway/highway provision and vehicle ownership relative to population and network length. Traffic exposure is additionally represented by passenger-car vehicle-kilometres where available. These indicators do not directly measure infrastructure quality or safety; rather, they describe the scale, structure and level of use of the road transport system and therefore provide important context for interpreting fatality trends (IRF, 2025).

Considerable differences are evident in the size and development of the road networks. Italy had by far the largest total road network among the five countries, increasing marginally by 0.4% over 2018–2023. Greece similarly maintained a largely stable network over this period, with only a nominal increase. In contrast, Estonia recorded a substantial increase in reported total road network length of 51.6%, with a corresponding increase in road-network density. Serbia also expanded its network, although at a considerably lower rate, by 3.6%, while Croatia experienced a slight reduction of 0.7%. These differences demonstrate that the countries operate within substantially different infrastructure contexts, which should be considered when comparing absolute numbers of crashes and fatalities. The WRS road-network dataset distinguishes between motorways/highways, main or national roads, secondary/regional roads and other roads, allowing these structural differences to be examined systematically.

Motorway and highway provision increased in all five countries between 2018 and 2023, although the scale of change varied considerably. Italy's motorway/highway network increased by 8.5%, while Serbia recorded an increase of 23.1% and Estonia 40.6%. The increases in Croatia and Greece were more limited, at 2.4% and 1.8%, respectively. These developments indicate continued investment and expansion of higher-capacity road infrastructure, but they should not be interpreted as direct evidence of improved road safety, since the safety performance of a network also depends on road design, traffic composition, operating speeds, maintenance and the interaction between different road-user groups.

Vehicle exposure shows another important dimension of the differences between the countries. The number of four-wheeled vehicles per 1,000 inhabitants increased in all five countries between 2018 and 2023. Italy retained the highest level, rising per 1,000 inhabitants by 6.6%, followed by Estonia, where the indicator increased by 12.5%. Greece increased by 13.6%, Croatia by 20.1%, and Serbia recorded the largest relative increase, per 1,000 inhabitants by 26.9%. This convergence towards higher levels of motorisation is relevant for road safety assessment because increasing vehicle availability can contribute to greater exposure to road traffic, while the relationship between motorisation and fatalities is mediated by infrastructure, vehicle safety, travel behaviour and enforcement.

A different picture emerges when the vehicle fleet is related to the length of the road network. Italy had the highest concentration of four-wheeled vehicles per kilometre of road, increasing by approximately 4.3% over the period 2018-2023. Croatia and Serbia also experienced increases, of 17.4% and 16%, respectively. Greece increased 10.7%. Estonia was the only country in which this indicator declined, by approximately 23%, despite an increase in the vehicle fleet per population. This reflects the substantial expansion of the reported road network and illustrates why exposure indicators should be interpreted jointly rather than in isolation.

Where traffic-volume data are available, the development of passenger-car vehicle-kilometres further illustrates changes in exposure. Passenger-car traffic increased by approximately 7.6% in Croatia and by 12.4% in Estonia. Vehicle-kilometres provide a more direct measure of traffic exposure than fleet size alone because they capture the amount of travel undertaken. However, differences in data availability and national reporting practices mean that these indicators should be used cautiously for cross-country comparisons. The methodological literature on international road-safety comparisons similarly emphasises that exposure measures such as vehicle-kilometres, vehicle fleets and road length capture different dimensions of risk and are not interchangeable (Papadimitriou et al., 2013).

Overall, the infrastructure and exposure indicators reveal substantial structural differences across the five Roads4All Use Case countries. Italy combines the largest road network and highest vehicle concentration per kilometre with the highest level of motorisation, whereas Estonia combines comparatively high motorisation with a rapidly expanding reported road network. Serbia shows the strongest growth in both motorisation and motorway provision, while

Croatia combines relatively high motorway availability with a comparatively smaller overall network. Greece, by contrast, shows relatively stable network characteristics but increasing vehicle ownership. These differences underline the importance of considering exposure and infrastructure context when interpreting the road-safety outcomes presented in the preceding sections. In particular, fatality rates based solely on population provide an important but incomplete picture of road-safety performance; complementary exposure indicators can help distinguish between changes associated with the scale and intensity of road use and those potentially reflecting differences in the underlying safety performance of the transport system.

5. DISCUSSION

5.1 Different performance profiles require different interventions

The benchmarking results demonstrate that the five Roads4All countries cannot be treated as a homogeneous group. Their differences in fatality rates and trends suggest different intervention priorities. Countries with persistently high fatality rates, such as Croatia and Serbia, may require stronger emphasis on systemic risk reduction, including infrastructure safety, speed management, enforcement and post-crash response. In these contexts, investment in road infrastructure should prioritise locations and road categories associated with the highest risk. Greece similarly exhibits a comparatively high fatality rate despite improvements compared with 2019. The persistence of elevated risk suggests that continued reductions will require interventions beyond isolated road safety measures and should increasingly focus on systemic approaches.

Italy presents a different challenge. Its fatality rate is below that of Croatia, Greece and Serbia but its progress since 2019 has been relatively limited. This illustrates that countries with comparatively moderate fatality rates may nevertheless face difficulties in achieving the rate of improvement required to meet long-term targets. Estonia represents another distinctive profile. Its historically comparatively favourable performance demonstrates that substantial road safety improvements are achievable, while recent increases illustrate the need for continuous monitoring and prevention of regression.

5.2 Implications for infrastructure investment

The results support a shift from reactive infrastructure investment towards risk-based prioritisation. Instead of focusing exclusively on locations where crashes have already occurred, road authorities can combine historical crash data with road characteristics, traffic exposure and infrastructure condition to identify locations with high potential risk. This is consistent with the Safe System principle that serious crashes should be prevented before they occur. Infrastructure-readiness assessments can complement traditional road safety indicators by identifying whether road networks provide the physical conditions required to accommodate human error. Such an approach is particularly relevant to the Roads4All project. Harmonised indicators can provide a high-level baseline for identifying countries or road categories requiring further assessment. More detailed infrastructure assessments can then be conducted at project or network level.

5.3 Value and limitations of international datasets

The IRF dataset provides several advantages for international benchmarking. First, its longitudinal structure enables trends to be examined over time rather than relying on individual observations. Second, its combination of safety, vehicle and infrastructure indicators allows

researchers to move beyond purely population-based comparisons. Third, its broad geographical coverage facilitates benchmarking between countries with different transport-system characteristics. Nevertheless, several limitations must be recognised. First, data availability is not uniform across countries and indicators. Some infrastructure and vulnerable-road-user indicators may have gaps or differences in definition. Second, national reporting practices can affect comparability. Third, population-based fatality rates do not directly measure mobility exposure. Finally, the relatively small number of countries in the Roads4All sample limits the statistical generalisability of the findings (González-Sánchez, et al., 2021).

The four-tier classification should therefore be interpreted as an exploratory benchmarking framework rather than a definitive performance index. Future research could strengthen the methodology by incorporating vehicle-kilometres travelled, passenger-kilometres, traffic volumes, road class, urbanisation and socioeconomic indicators.

6. CONCLUSIONS

This paper has examined road safety performance across Estonia, Greece, Croatia, Serbia and Italy using indicators from the International Road Federation Road Safety Dataset. The analysis demonstrates substantial differences in road safety outcomes despite shared European objectives and an overall long-term downward trend in road fatalities. The comparison confirms that population-based fatality rates remain an important indicator of national road safety performance but should not be interpreted in isolation. Vehicle fleet, road network, vulnerable road user and infrastructure indicators provide additional dimensions that can help explain differences between countries and identify potential intervention areas.

The results also demonstrate the importance of longitudinal analysis. Short-term changes, particularly during the COVID-19 pandemic, can obscure underlying trends. Comparing performance against a pre-pandemic baseline provides a more meaningful assessment of progress towards the 2030 target. The proposed exploratory four-tier benchmarking framework provides a practical mechanism for translating complex datasets into an accessible basis for peer comparison. Rather than establishing an absolute ranking, the framework supports the identification of countries with similar performance profiles and highlights areas where additional investigation or intervention may be warranted. Before the framework is used as a formal classification tool, explicit tier-assignment rules should be defined and tested.

For the Roads4All project, the findings underline the importance of integrating road safety performance data with infrastructure-readiness assessments. Harmonised datasets such as the IRF World Road Statistics can provide a strategic evidence base for identifying disparities, supporting investment prioritisation and monitoring progress. At the same time, national and local-level data remain necessary to understand the underlying causes of observed differences. Ultimately, achieving Vision Zero requires a transition from fragmented road safety interventions towards integrated, data-driven and system-based approaches. Internationally comparable road safety indicators can contribute to this transition by making differences in performance visible, enabling knowledge transfer and supporting evidence-based investment decisions. Their greatest value lies not in ranking countries, but in helping decision-makers understand where risks persist, where progress is being achieved, and which interventions may contribute most effectively to safer and more resilient road transport systems.

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7. REFERENCES

[1] European Commission, Directorate-General for Mobility and Transport. *2023 figures show stalling progress in reducing road fatalities in too many countries*. Brussels, 2024.
[2] European Commission / Transport Community. *Road safety statistics 2023 – Preliminary road fatality data for the Western Balkan region*. Brussels, 2024.
[3] European Commission, Directorate-General for Mobility and Transport. *Road safety in the EU: fatalities below pre-pandemic levels but progress remains too slow*. Brussels, 2023.
[4] European Commission. *EU Road Safety Policy Framework 2021–2030: Next steps towards "Vision Zero"*. Brussels: European Commission, 2019.
[5] González-Sánchez, G., Olmo-Sánchez, M. I., Maeso-González, E., Gutiérrez-Bedmar, M., & García-Rodríguez, A. (2021). Needs for International Benchmarking of Road Safety Management Based on Mobility Exposure Measures and Risk Patterns. International Journal of Environmental Research and Public Health, 18(23), 12851. https://doi.org/10.3390/ijerph182312851.
[6] Papadimitriou, E., Yannis, G., Bijleveld, F., & Cardoso, J. L. (2013). Exposure data and risk indicators for safety performance assessment in Europe. Accident Analysis & Prevention, 60, 371–383. https://doi.org/10.1016/j.aap.2013.04.040.
[7] International Road Federation (IRF). IRF World Road Statistics and Data Warehouse. Geneva: International Road Federation.
[8] World Health Organization. *Save LIVES: A Road Safety Technical Package*. Geneva: WHO, 2017.
[9] World Health Organization. *Global Status Report on Road Safety 2023*. Geneva: WHO, 2023.
[10] World Health Organization (WHO). Road Traffic Injuries. Geneva: WHO, 2026.