



Faculty of Engineering
University of Kragujevac



Ministry of Science, Technological
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Motor Vehicles & Motors 2026
ECOLOGY -
VEHICLE AND ROAD SAFETY
- EFFICIENCY
Proceedings**



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FOREWORD

For 47 years, a traditional international gathering - originally known as a Symposium and, since 2006, as the "Motor Vehicles and Motors" Congress - has been held biennially at the Faculty of Engineering (formerly the Faculty of Mechanical Engineering) of the University of Kragujevac. This year, the 11th International Congress "Motor Vehicles and Motors" took place in Kragujevac on October 8th–9th, 2026, under the traditional motto: "Ecology – Vehicle and Road Safety – Efficiency".

A large number of authors from both the country and abroad responded to the organizers' invitation, resulting in numerous high-quality submissions across the event's core areas: "Power Train Technology," "Vehicle Design and Manufacturing," "Vehicle Dynamics and Intelligent Control Systems," "Driver/Vehicle Interface, Information Systems, and Assistance Systems," and "Transport Challenges in Emerging Economies." Additionally, two topics were officially introduced for the first time: "Artificial Intelligence in Automotive Technology" and "Autonomous Vehicles".

A total of 63 papers were accepted for presentation following a rigorous peer-review process. The presentations were organized into sessions, including a newly introduced poster session dedicated to students and young researchers.

The Congress organizers extend their special gratitude to the distinguished scientists in the fields of motor vehicles and transportation who agreed to deliver three inspiring introductory lectures addressing the heart of contemporary issues in the sector: prof. dr Ralph Putz (Landshut University of Applied Sciences, Germany), prof. dr Aleksandar Stevanović (University of Pittsburgh, USA), and prof. dr. Isak Karabegović (Academy of Sciences and Arts of Bosnia and Herzegovina, Bosnia and Herzegovina).

We extend our sincere gratitude to the esteemed members of the Congress Scientific Committee—who also served as reviewers for the papers submitted for presentation—for their significant contribution to the overall quality of the accepted papers.

The organization of the Congress was once again supported by the Ministry of Science, Technological Development and Innovation of the Republic of Serbia, the Faculty of Engineering of the University of Kragujevac, and the International journal "Mobility & Vehicle Mechanics" and we sincerely thank them for their support.

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PREDGOVOR

Već 47 godina, svake druge godine, na Fakultetu inženjerskih nauka (nekada Mašinskom fakultetu) Univerziteta u Kragujevcu održava se tradicionalan međunarodni skup, nekada nazivan Simpozijum, a od 2006. godine - Kongres „Motorna vozila i motori“. Ovogodišnji, 11. Međunarodni kongres „Motorna vozila i motori“ održan je u Kragujevcu od 8. do 9. oktobra 2026. godine, uz tradicionalni moto „Ekologija – Vozilo i bezbednost na putu – Efikasnost“.

Na poziv organizatora odazvao se veliki broj autora iz zemlje i inostranstva, što je donelo veliki broj prijavljenih kvalitetnih radova iz glavnih oblasti skupa: „Tehnologija pogonskog sistema“, „Dizajn i proizvodnja vozila“, „Dinamika vozila i inteligentni upravljački sistemi“, „Interfejs vozač/vozilo, informacioni sistemi i sistemi za pomoć“, „Transportni izazovi ekonomija u usponu“, uz prvi put zvanično promovisane teme – „Veštačka inteligencija u automobilskoj tehnologiji“ i „Autonomna vozila“.

Ukupan broj od 63 radova je prihvaćen za prezentaciju posle rigoroznog procesa recenziranja. Rad je organizovan po sekcijama, uz prvi put promovisanu poster sekciju namenjenu za studente i mlade istraživače.

Organizatori Kongresa su posebno zahvalni istaknutim naučnicima iz oblasti motornih vozila i saobraćaja koji su pristali da održe tri inspirativna uvodna predavanja koja zadiru u srž savremenih pitanja vezana za vozila i saobraćaj, a to su: prof. dr Ralph Putz (Landshut University of Applied Sciences, Nemačka), prof. dr Aleksandar Stevanović (University of Pittsburgh, SAD) i prof. dr Isak Karabegović (Akademija nauka i umjetnosti Bosne i Hercegovine, Bosna i Hercegovina).

Veliku zahvalnost dugujemo našim dragim članovima Naučnog odbora Kongresa, ujedno i recenzentima radova prijavljenih za prezentaciju na Kongresu, koji su mnogo doprineli ukupnom kvalitetu konačno prihvaćenih radova.

Organizaciju Kongresa i ovog puta su podržali: Ministarstvo nauke, tehnološkog razvoja i inovacija Republike Srbije, Fakultet inženjerskih nauka Univeziteta u Kragujevcu i Međunarodni časopis „Mobility & Vehicle Mechanics“, na čemu im se iskreno zahvaljujemo.

Naučni odbor i Organizacioni odbor Kongresa MVM2026

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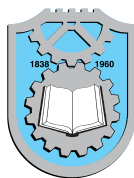
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PREDICTION AND TIME-SERIES ANALYSIS OF ROAD DEATHS PER MILLION INHABITANTS IN THE REPUBLIC OF SERBIA AND THE EUROPEAN UNION FOR THE PERIOD 2012 TO 2030

ABSTRACT: The number of road traffic fatalities remains a significant road safety concern in the Republic of Serbia. This study aimed to identify an appropriate forecasting model for monitoring and predicting road traffic fatalities and to assess whether the target of the Decade of Action for Road Safety 2021–2030, which aims to reduce road traffic fatalities by 50% by 2030, is likely to be achieved. Three time-series forecasting models available in MINITAB software were applied: the linear trend model, quadratic trend model, and growth model. Forecasted values were compared with observed data, and the quadratic trend model demonstrated the highest forecasting accuracy, exhibiting the lowest percentage error for the period from 2012 to 2022. Therefore, this model was selected to predict road deaths per million inhabitants in Serbia for the period from 2022 to 2030. The results indicate a substantial projected increase in road fatalities during this period, representing an unfavorable trend for road safety. A comparative analysis with the European Union showed that road deaths per million inhabitants decreased by approximately 13% in Serbia between 2012 and 2022, compared with an average decrease of approximately 15% in the EU. Overall, the findings suggest that the 2030 target is unlikely to be achieved under current trends without additional interventions and systematic safety measures.

KEYWORDS: time-series analysis, road deaths per million inhabitants, traffic safety, MINITAB

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PREDIKCIJA I ANALIZA VREMENSKIH SERIJA BROJA POGINULIH U SAOBRAĆAJNIM NEZGODAMA NA MILION STANOVNIKA U REPUBLICI SRBIJI I EVROPSKOJ UNIJI ZA PERIOD OD 2012. DO 2030. GODINE

REZIME: Broj poginulih u saobraćajnim nezgodama i dalje predstavlja značajan problem bezbednosti saobraćaja u Republici Srbiji. Cilj ovog istraživanja bio je da se identifikuje odgovarajući model za praćenje i predviđanje broja poginulih u saobraćajnim nezgodama, kao i da se proceni da li će cilj Dekade akcije za bezbednost saobraćaja 2021–2030, koji podrazumeva smanjenje broja poginulih u saobraćajnim nezgodama za 50% do 2030. godine, biti ostvaren. Primenjena su tri modela za predviđanje zasnovana na analizi vremenskih serija u softveru MINITAB: linearni trend model, kvadratni trend model i model rasta. Predviđene vrednosti upoređene su sa stvarnim podacima, pri čemu je kvadratni trend model pokazao najveću tačnost predviđanja, sa najmanjom procentualnom greškom za period od 2012. do 2022. godine. Zbog toga je ovaj model odabran za predviđanje broja poginulih na milion stanovnika u Srbiji za period od 2022. do 2030. godine. Rezultati ukazuju na značajan projektovani porast broja poginulih u posmatranom periodu, što predstavlja nepovoljan trend sa aspekta bezbednosti saobraćaja. Uporedna analiza sa Evropskom unijom pokazala je da je broj poginulih na milion stanovnika u Srbiji smanjen za približno 13%, dok je prosečno smanjenje u EU iznosilo oko 15%. Rezultati ukazuju da ostvarenje cilja do 2030. godine nije verovatno bez dodatnih intervencija i sistematskih mera za unapređenje bezbednosti saobraćaja.

KLJUČNE REČI: analiza vremenskih serija, broj poginulih u saobraćaju na milion stanovnika, bezbednost saobraćaja, MINITAB

INTRODUCTION

In the prediction of traffic accidents, in addition to traditional statistical methods, machine learning and deep learning techniques can also be applied. In recent years, increasing attention has been devoted to regression-based time-series models, as evidenced by the substantial number of publications addressing this topic in the scientific literature. Time-series analysis can be applied across a wide range of fields whenever a large number of events are observed over a specified period of time.

Examples include the number of defective products per unit of working time in industrial quality control, the number of stock market transactions per minute, the number of vehicles passing through a particular intersection or road section within a specified time interval, and the number of vehicles parked in a parking facility over a given period. Similarly, time-series methods can be applied to the analysis and prediction of traffic accidents occurring within different time intervals, such as 15 minutes, one hour, 24 hours, one week, one month, one year, three years, five years, or ten years.

Table 1 presents various statistical methods used for the prediction of road traffic accidents. The final three studies Gošić et al. (2022), Derentić et al. (2022), and Micić et al. (2022) present research conducted in the Republic of Serbia.

Table 1 Overview of different statistical methods for predicting road car accidents

Authors	Method
Khasnabis and Lyoo (1989)	Autoregressive Integrated Moving Average (ARIMA)
Bener et al. (2010)	Regression Analysis & Time-Series Data
Commandeur et al. (2013)	Traditional Regression Models (Linear, Generalized Linear & Non-Linear), ARMA-type & DRAG approaches
Mutangi (2015)	Autoregressive Integrated Moving Average (ARIMA)
Darma (2017)	Autoregressive Integrated Moving Average Model, Transfer Function-Noise Model & State-Space Model
Parvareh et al. (2018)	Autoregressive Integrated Moving Average (ARIMA) & Seasonal Autoregressive Integrated Moving Average (SARIMA)
Abdulhafedh (2018)	Poisson, Negative Binomial, Zero-Inflated, Logit and Probit, Neural Networks
Nanga (2019)	Seasonal Autoregressive Integrated Moving Average (SARIMA)

Table 1 (continuation)

Authors	Method
Jalalian (2019)	Autoregressive integrated moving average (ARIMA) & Prophet
Samson and Adewale (2020)	Time-Series Analysis (Quadratic, Growth & Linear)
Jomnonkwao et al. (2020)	Time-Series Analysis, Curve Estimation, Regression Analysis & Path Analysis
Getahun (2021)	Autoregressive Integrated Moving Average (ARIMA)
Vipin and Thekkedath (2021)	The Exploratory Data Analysis & Time-Series Regression
Sumit et al. (2021)	Time series analysis
Kaunitz (2022)	Logistic Regression & Time-Series Analysis
Khasawneh et al. (2022)	Time-Series Analysis
Cai and Di (2023)	Boosting, Autoregressive Integrated Moving Average (ARIMA) & Time-Series Count Data Model,
Gošić et al. (2022)	Chi-Squared Test, Student's t-Test, Linear Regression Analysis & Logarithmic Regression
Deretić et al. (2022)	Seasonal Autoregressive Integrated Moving Average (SARIMA)
Mićić et al. (2022)	Poisson, Negative Binomial, Random Effect Negative Binomial, Zero-Inflated Poisson & Zero-Inflated Negative Binomial Models

RESEARCH METHOD

Reporting on the state of traffic safety represents an integral component of the traffic safety monitoring process, contributing to the establishment and continuous improvement of the traffic safety system and supporting effective traffic safety management within a specific geographical area. In the Republic of Serbia, the development and state of traffic safety can be observed and analysed through five distinct stages, each characterized by specific trends, conditions, and developments.

The first stage covers the period from 1981 to 1990, followed by the second stage from 1991 to 2000 and the third stage from 2001 to 2010. The fourth stage encompasses the period from 2011 to 2020, while the fifth stage covers the period from 2021 to 2030. Each of these stages has its own specific characteristics, reflecting changes in traffic conditions, road safety policies, institutional frameworks, and measures implemented to improve traffic safety.

Improvements in road safety cannot be achieved through the efforts of an individual or a single institution alone. Continuous enhancement of cooperation and coordination among all relevant stakeholders is essential, particularly through the active involvement of academic and research institutions, the private sector, civil society organizations, the media, road traffic accident victims, and their families.

Although the Republic of Serbia, like most countries in the region, has adopted a national road safety strategy, the significance of this document has not been sufficiently promoted. Furthermore, key stakeholders do not always fully recognize or implement its objectives, while the implementation and achievement of the established goals are not systematically monitored. Consequently, the overall results remain unsatisfactory.

In order to improve the current situation, it is necessary for each local community to adopt its own strategic road safety documents, establish ambitious yet achievable objectives, and mobilize all available local resources. Through the continuous implementation of proven and effective measures, local communities can work systematically toward achieving their defined road safety goals, in accordance with the recommendations of Road Safety in Local Communities (2023).

Analysing the state of traffic safety within a specific area or along a particular road section represents an essential task in the field of traffic safety management. Measures and activities aimed at improving the level of traffic safety should be continuously assessed and further developed through systematic analyses, comparisons, and evaluations of the prevailing traffic safety conditions.

Comparative analyses involving appropriate reference areas can contribute significantly to the improvement and optimization of road safety measures and interventions. Average values within the same country for areas with similar characteristics, as well as data from comparable areas in OECD or European Union countries, may be used as reference benchmarks.



Figure 1 Stages of the state of traffic safety in the Republic of Serbia

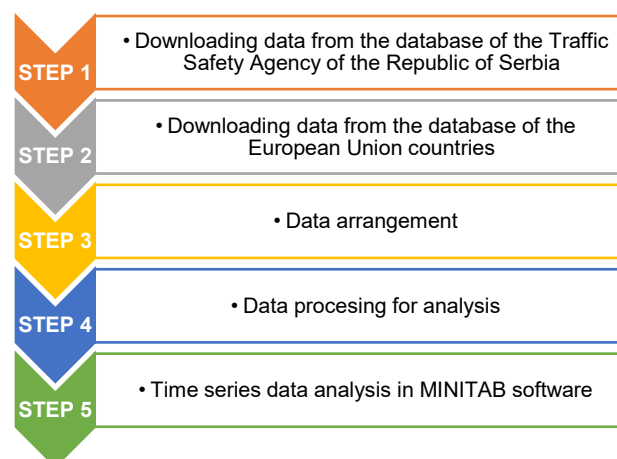


Figure 2 Study procedure

The level of traffic safety can be assessed using both direct and indirect indicators, as well as absolute and relative traffic safety indicators. However, for the purposes of comparative analysis, relative traffic safety indicators are generally considered more appropriate, as they enable meaningful comparisons between areas with different population sizes, traffic volumes, or other relevant characteristics.

$$\text{Road deaths per milion inhabitatnts} = \frac{\text{Road deaths}}{\text{Inhabitants}} \cdot 1\,000\,000 \quad (1)$$

In some countries, road traffic safety analyses take into account not only fatalities but also persons who have sustained slight or serious injuries. To account for differences in the severity of road traffic injuries, appropriate weighting factors are applied. This approach enables the conversion of absolute indicators into composite relative indicators that provide a more comprehensive assessment of the level of road traffic safety. In the Republic of Serbia, for example, Equation (2) is used:

$$\text{PWCR} = \frac{\text{SPI} \cdot \text{WF}_1 + \text{SI} \cdot \text{WF}_2 + \text{D} \cdot \text{WF}_3}{\text{Inhabitants}} \cdot 10\,000 \quad (2)$$

PWCR - public weighted casualty risk
SPI - slightly physically injured
SI - seriously injured

D - dead

WF₁ – weighting factor for slightly physically injured (WF₁=1)

WF₂ – weighting factor for seriously injured (WF₂=13)

WF₃ – weighting factor for dead (WF₃=99)

A direct comparison between the Republic of Serbia and the European Union would only be possible if all EU Member States collected and reported traffic safety data using the same definitions and weighting factors as those applied in the Republic of Serbia. However, this condition is not met, as national definitions of a seriously injured person in road traffic collisions differ among EU Member States. Consequently, a comparison based on injury-severity weighting factors is not methodologically appropriate. Therefore, Eq. (1) is used for the subsequent analysis.

The aim of this study is to analyse historical trends and forecast future trends in road fatalities per million inhabitants using time-series analysis implemented in the MATLAB software environment for the Republic of Serbia and the European Union. The analysis seeks to assess whether the target of reducing public road safety risk by 50%, as defined in the "Improving Global Road Safety" strategy, is likely to be achieved.

RESEARCH DATA

The data used in the first part of the analysis were obtained from the database of the Road Traffic Safety Agency of the Republic of Serbia. The dataset contains information on road fatalities per million inhabitants per year for the period from 2012 to 2022. These data were analysed using the MINITAB statistical software package.

MINITAB is a statistical data analysis software package that provides a range of tools for statistical analysis, including hypothesis testing, regression analysis, and analysis of variance (ANOVA). In this study, time-series models were developed to analyse historical trends and forecast the rate of road traffic fatalities in the Republic of Serbia over the period 2012–2022.

Trend analysis in MINITAB is a time-series forecasting approach used to identify and describe the underlying long-term movement of a variable over time and to generate forecasts for future periods. MINITAB provides several trend models, including the linear, quadratic, exponential growth, and S-curve models. Trend analysis is particularly appropriate when the observations exhibit a relatively consistent trend and do not contain a pronounced seasonal component.

The linear trend model assumes that the variable changes at a relatively constant rate over time. The model is expressed as:

$$Y_t = \beta_0 + \beta_1 \cdot t + e_t \quad (3)$$

where Y_t represents the observed value at time t , β_0 is the constant, β_1 represents the average change from one period to the next, and e_t represents the random error. Consequently, a linear model is appropriate when the graphical representation of the time series indicates an approximately straight-line trend.

The quadratic trend model is applied when the time series exhibits curvature and the rate of change is not constant over time. Its general form is:

$$Y_t = \beta_0 + \beta_1 \cdot t + \beta_2 \cdot t^2 + e_t, \quad (4)$$

where the additional t^2 term enables the model to capture a curved trend. Therefore, compared with the linear model, the quadratic model can better represent situations in which the rate of increase or decrease changes throughout the observation period.

The growth curve model, referred to by MINITAB as the exponential growth trend model, is used when the time series demonstrates exponential growth or decline. The model is expressed as:

$$Y_t = \beta_0 \cdot \beta_1^t \cdot e_t \quad (5)$$

Changes in the observed variable are represented in terms of a multiplicative rather than a constant absolute change. This model is therefore suitable for time series in which the rate of change becomes progressively larger or smaller as time increases.

After estimating the selected trend model, MINITAB calculates fitted values and uses the estimated trend equation to obtain forecasts for future time periods. The suitability of different trend models can be assessed by comparing forecasting accuracy measures such as MAPE (Mean Absolute Percentage Error), MAD (Mean Absolute Deviation), and MSD (Mean Squared Deviation). In general, lower values indicate better model performance. However, MINITAB recommends that these numerical measures should not be considered independently, the fitted trend should also be examined graphically, particularly toward the end of the observed time series (Minitab, LLC).

The dataset used in the analysis is presented in Appendix A, Table A1. The data used in the second part of the analysis were obtained from the European Transport Safety Council (2023). The dataset contains information on road fatalities per million inhabitants for 2012 and 2022 for European countries, including the Republic of Serbia. Appendix B, Table B1, presents the ISO country codes and the corresponding values of road fatalities per million inhabitants for 2012 and 2022, which were used in the subsequent analyses.

ANALYSIS OF ROAD DEATHS PER MILLION INHABITANTS IN THE REPUBLIC OF SERBIA

The analysis of road deaths per million inhabitants provides an important basis for assessing the level of road safety and identifying changes in traffic mortality over time. In order to obtain a comprehensive overview of the road safety situation in the Republic of Serbia, the analysis is divided into several periods, allowing both historical trends and future projections to be considered. Particular attention is given to the period from 2012 to 2022, followed by an assessment of the projected trends from 2023 to 2030, while the overall period from 2012 to 2030 is considered in order to identify long-term developments and the expected direction of change in road mortality.

Analysis of road deaths per million inhabitants in Republic of Serbia in period from 2012 to 2022

MINITAB is a statistical data analysis software package that provides a range of tools for conducting statistical analyses, including hypothesis testing, regression analysis, and analysis of variance (ANOVA). The objective of this study is to develop time-series models for analysing historical trends and forecasting the rate of road traffic fatalities in the Republic of Serbia over the period from 2012 to 2022. The dataset used for the analysis is presented in Appendix C, Table C1.

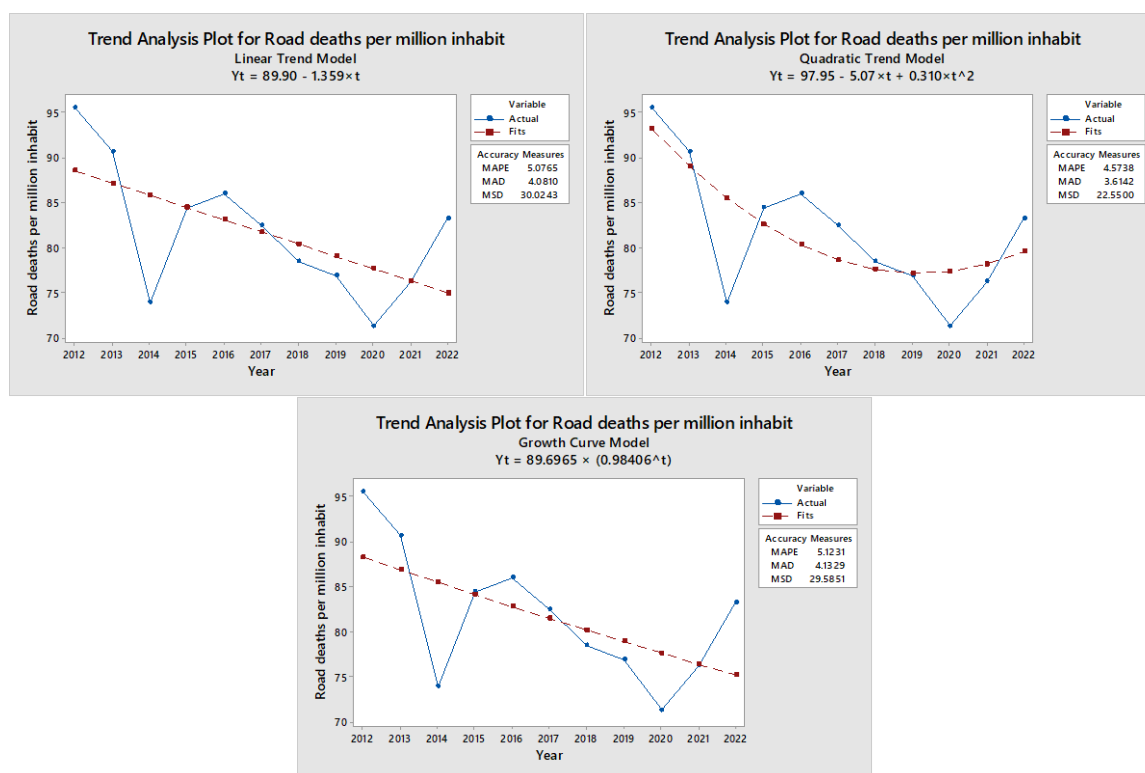


Figure 3 Graph of comparison of the Actual and Predicted Data in period from 2012 to 2022; Linear trend model, Quadratic trend model and Growth curve model, respectively

Following the completion of the time-series analysis, the forecast values generated by the respective models can be compared with the observed values over the ten-year period. As shown in Figure 3, the quadratic trend model

provides the closest fit to the observed data, exhibiting the lowest percentage error among the models considered. Therefore, the quadratic trend model, represented by Equation (6), was identified as the most appropriate model for forecasting road traffic fatalities in the Republic of Serbia for the analysed period from 2012 to 2022.

$$Y_t = 97.75 - 5.07 \cdot t + 0.310 \cdot t^2 \quad (6)$$

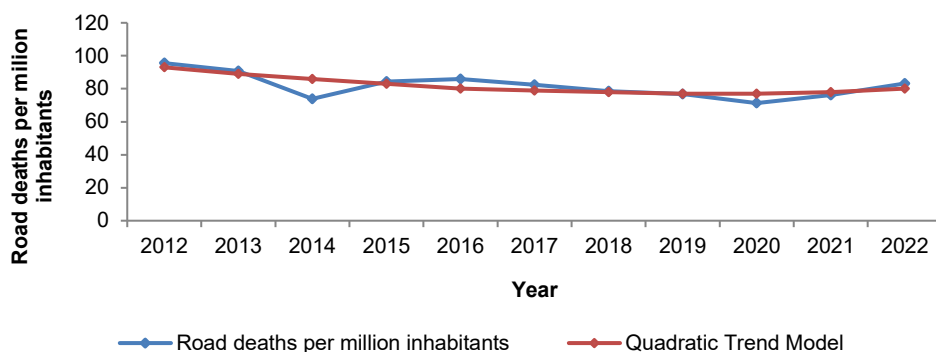


Figure 4 Comparison of road deaths per million inhabitants with the adopted model (quadratic model trend) in Republic of Serbia from 2012 to 2022

Figure 4 shows the comparison of road deaths per million inhabitants with the adopted model (quadratic model trend) in the Republic of Serbia from 2012 to 2022. This model deviates the least from the actual model as it is shown.

Analysis of road deaths per million inhabitants in Republic of Serbia in period from 2023 to 2030

The analysis of road deaths per million inhabitants in the Republic of Serbia in period from 2023 to 2030 was performed by using the Quadratic model Eq. (1) trend which proved to be a reference.

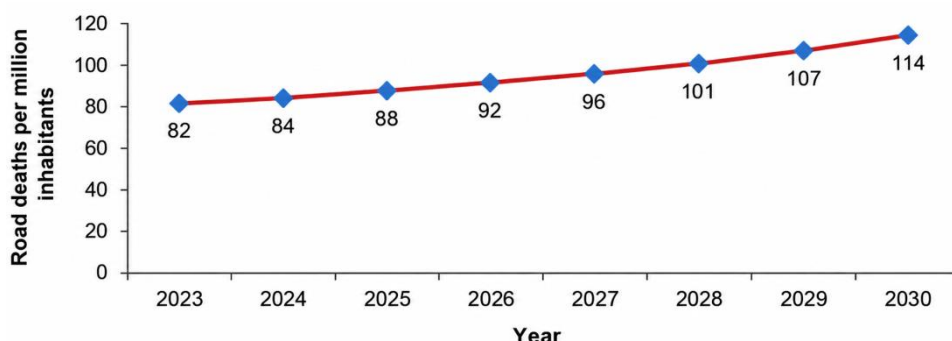


Figure 5 Prediction of road deaths per million inhabitants for the period from 2023 to 2030 using Quadratic model trend

Figure 5 indicates that, according to the quadratic trend model, the number of road fatalities per million inhabitants is projected to increase over the period from 2023 to 2030. This finding is particularly significant for the further analysis of road safety in the Republic of Serbia, which has set the objective of reducing the number of road fatalities per million inhabitants by 50% during the 2021–2030, defined by Decade of Action for Road Safety 2021–2030. The projected upward trend therefore indicates a potential divergence from the established road safety target and highlights the need for further analysis and the implementation of appropriate road safety measures.

Analysis of road deaths per million inhabitants in the Republic of Serbia from 2012 to 2030

This chapter presents an analysis of road fatalities per million inhabitants in the Republic of Serbia for the period from 2012 to 2030. The analysis was conducted using a quadratic trend model. Based on the observed data for the period from 2012 to 2022, forecasts were generated for the period from 2023 to 2030. The purpose of the analysis is to assess whether the target of reducing public road safety risk by 50%, as defined in the Improving Global Road Safety strategy, is likely to be achieved.

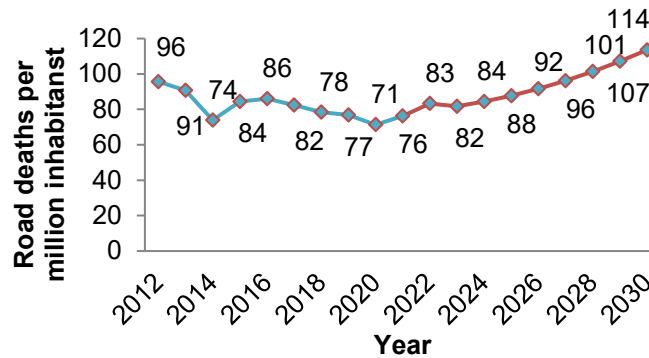


Figure 6 Prediction of road deaths per million inhabitants for the period from 2012 to 2030 using Quadratic model trend

As shown in Figure 6, the quadratic trend model forecasts the number of road fatalities per million inhabitants in the Republic of Serbia for the period from 2012 to 2030. The number of road fatalities per million inhabitants was 96 in 2012 and 83 in 2022, while the model projects a value of 144 fatalities per million inhabitants by 2030. Although a declining trend was observed between 2012 and 2022, the forecast indicates a substantial increase in road fatalities per million inhabitants over the period from 2023 to 2030. This projected trend is highly unfavourable from the perspective of road safety in the Republic of Serbia.

These findings indicate the need for a comprehensive assessment of the current road safety situation, including a detailed analysis of the underlying causes and contributing factors of road traffic accidents. Particular attention should be devoted to the identification of critical risk factors and to the development and implementation of targeted road safety measures and public awareness campaigns aimed at reversing the projected negative trend.

The results also indicate that the objectives established under the previous National Road Traffic Safety Strategy for the period 2015–2020 were not fully achieved. In particular, the planned increase in seat belt use was not attained, with particularly unfavourable results concerning seat belt use in rear seats. The intended reduction in speeding on Serbian roads was likewise not achieved, while the targeted level of child restraint system use remained unmet. Instead of increasing, helmet use among motorcycle riders declined. Furthermore, the planned reduction in driving under the influence of alcohol was not achieved, and the systematic application of road infrastructure safety assessment and improvement tools remained insufficient.

The situation concerning child road traffic injuries is particularly concerning, as the expected reduction in child injuries and the elimination of child fatalities were not achieved. On the contrary, an increase in the number of children killed and injured in road traffic was recorded. These shortcomings highlight the need for more effective implementation, coordination, and systematic monitoring of road safety measures and activities envisaged within the Decade of Action for Road Safety 2021–2030. Continuous monitoring of the implementation and effectiveness of these measures is essential to ensure progress toward the established road safety objectives and to prevent the continuation of the projected adverse trend.

ANALYSIS OF ROAD DEATHS PER MILLION INHABITANTS IN THE EUROPEAN UNION IN 2012 AND 2022

Road fatalities per million inhabitants in the European Union were analyzed for 2012 and 2022 in order to assess the changes achieved during this period, compare the road safety performance of the Republic of Serbia with that of EU Member States, and evaluate Serbia's position relative to the EU average. The data used in the analysis were obtained from the European Transport Safety Council (2023). The dataset, presented in Appendix D, Table D1, contains data on road fatalities per million inhabitants for European countries for the period from 2012 to 2022 and was analyzed using the MINITAB statistical software package.

A separate trend model was developed for each country. The most appropriate model was selected according to the minimum error criterion, with the corresponding results presented in Appendix D, Table D1. Using MINITAB, time-series trend analyses of road fatalities per million inhabitants were performed for the European countries based on the 2012 data, as illustrated in Figure 7.

For the Republic of Serbia, the Growth Curve model was identified as the most appropriate model according to the minimum error criterion. For the EU countries as a whole, the Quadratic Trend model, given by Equation (7), was identified as the most appropriate model based on the same criterion for the 2012 analysis.

$$Y_t = 23.4068 \cdot (1.03875^t) \quad (7)$$

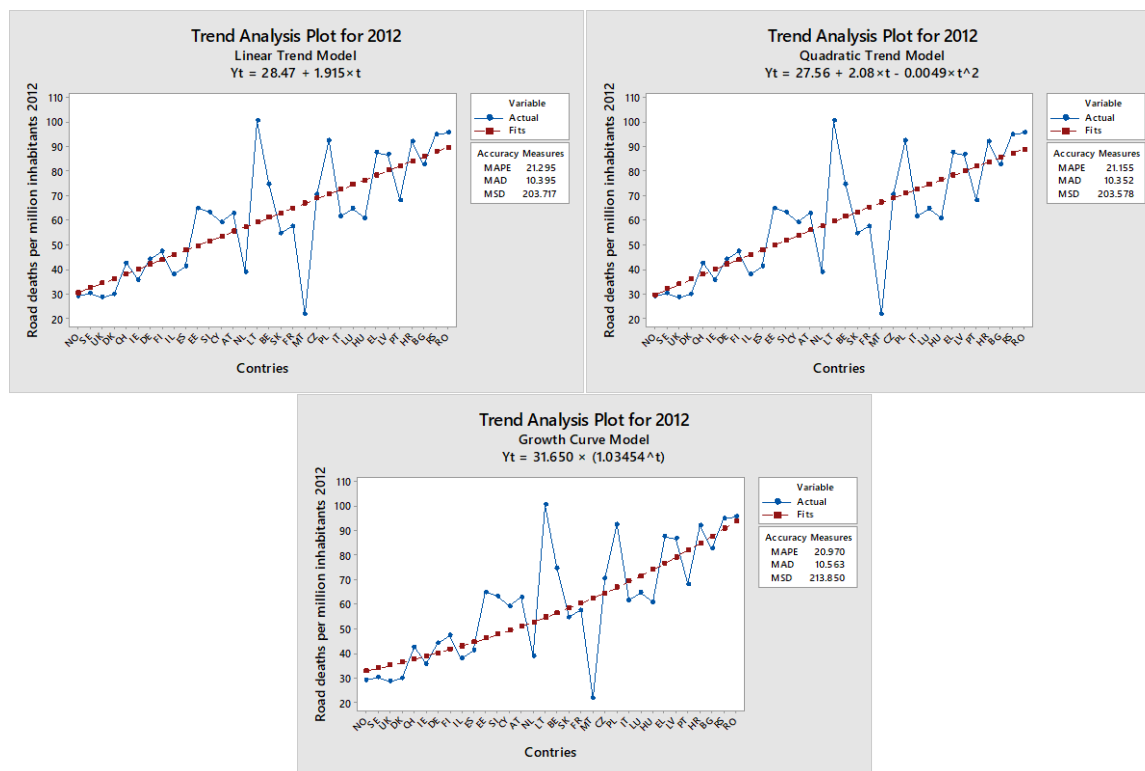


Figure 8 Time series analysis of road deaths per million inhabitants in 2022 in the EU

For 2022, a trend model was likewise selected for each country based on the minimum error criterion. The corresponding results are presented in Appendix E, Table E1. Using the MINITAB statistical software package, time-series trend analyses of road fatalities per million inhabitants for 2022 were performed for the European countries, as shown in Figure 8.

For the Republic of Serbia, no single trend model can be identified as the best model based solely on the minimum error criterion. As shown in Table E1, the Quadratic Trend and Growth Trend models produce the same percentage error. Therefore, neither model can be considered superior to the other according to this criterion alone.

For the comparative analysis of all European Union countries, the Growth Trend model, represented by Equation (8), was selected as the most appropriate model for 2022 based on the minimum percentage error criterion.

$$Y_t = 23.4068 \cdot (1.03875^t) \quad (8)$$

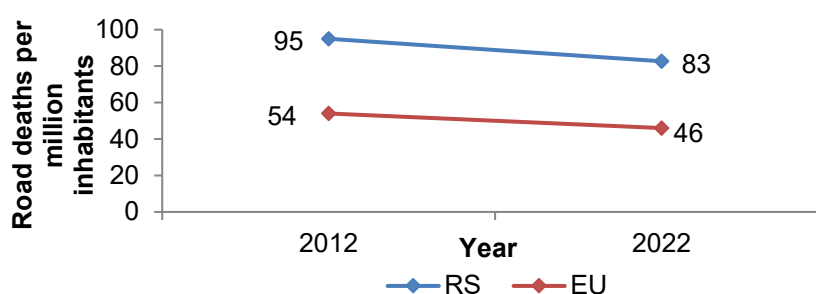


Figure 9 Comparative analysis of the road deaths per million inhabitants of the Republic of Serbia and the European Union for 2012 and 2022

Figure 9 presents a comparative analysis of road fatalities per million inhabitants in the Republic of Serbia and the European Union in 2012 and 2022. Over the ten-year period, the number of road fatalities per million inhabitants decreased by approximately 13% in the Republic of Serbia, while the European Union recorded an average reduction of approximately 15%. These results indicate that, although road safety improved in both the Republic of Serbia and the European Union during the observed period, the overall reduction in road fatalities per million inhabitants was slightly greater at the EU level.

CONCLUSIONS

This paper presents time-series models for analysing and forecasting road fatalities per million inhabitants in the Republic of Serbia and the European Union. The primary objective is to develop a statistical model capable of predicting future trends in road fatalities in the Republic of Serbia and assessing whether the target established under the Decade of Action for Road Safety 2021–2030 will be achieved.

The results indicate that the number of road fatalities per million inhabitants in the Republic of Serbia is projected to increase from 83 in 2022 to 144 by 2030. Consequently, based on the forecasts obtained, the objective of reducing road fatalities by 50% by 2030 is unlikely to be achieved.

The findings also emphasize the importance of addressing the shortcomings identified during the implementation of the previous road safety strategy. Measures and objectives that were not successfully achieved should be given particular attention within the current strategic framework. This requires the systematic organization, implementation, coordination, and continuous monitoring of the measures and activities envisaged under the Decade of action for road safety 2021–2030, with the aim of improving road safety performance and reversing the projected adverse trend.

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APPENDICES

Appendix A

Table A1 Road deaths per million inhabitants in the Republic of Serbia in period from 2012 to 2022

Year	Road deaths per million inhabitants in the Republic of Serbia
2012	96
2013	91
2014	74
2015	84
2016	86
2017	82
2018	78
2019	77
2020	71
2021	76
2022	83

Appendix B

Table B1 ISO code for European countries and road deaths per million inhabitants in the EU for 2012 and 2022

Country	ISO Code	2012	2022
Austria	AT	63	41
Belgium	BE	75	45
Bulgaria	BG	83	78
Croatia	HR	92	71
Cyprus	CY	59	41
Czech	CZ	71	50
Denmark	DK	30	26
Estonia	EE	65	38
Finland	FI	47	34
France	FR	58	48
Germany	DE	44	33
Greece	EL	88	61
Hungary	HU	61	55
Ireland	IE	36	31
Italy	IT	62	54
Latvia	LV	87	60
Lithuania	LT	100	43
Luxembourg	LU	65	56
Malta	MT	22	50
The Netherlands	NL	39	42
Poland	PL	93	50
Portugal	PT	68	62
Romania	RO	96	86
Slovakia	SK	55	45
Slovenia	SI	63	40
Spain	ES	41	37
Sweden	SE	30	22
United Kingdom	UK	29	26
Israel	IL	38	37
Norway	NO	29	21
Serbia	RS	95	83
Switzerland	CH	43	28

Appendix C

Table C1 Road deaths per million inhabitants in the Republic of Serbia in period from 2012 to 2022

Year	Road deaths per million inhabitants	Linear Trend Model	Quadratic Trend Model	Growth Curve Model	% error (Linear)	% error (Quadratic)	% error (Growth)
2012	96	89	93	88	6.8	2.7	7.9
2013	91	87	89	87	4.1	1.9	4.1
2014	74	86	86	85	-16.4	-16.4	-15.0
2015	84	84	83	84	0.5	1.7	0.5
2016	86	83	80	83	3.5	7.0	3.5
2017	82	82	79	81	0.6	4.2	1.8
2018	78	80	78	80	-1.9	0.6	-1.9
2019	77	79	77	79	-2.7	-0.1	-2.7
2020	71	78	77	78	-9.4	-8.0	-9.4
2021	76	76	78	76	0.3	-2.3	0.3
2022	83	75	80	75	9.9	3.9	9.9

Appendix D

Table D1 Comparison of real data and the data obtained by time series analysis of road deaths per million inhabitants in 2012 in the EU

Country	Real data	Linear Trend Model	Quadratic Trend Model	Growth Curve Model	% error (Linear)	% error (Quadratic)	% error (Growth)
NO	29	30	30	33	-3.2	-3.2	-13.5
SE	30	32	32	34	-6.5	-6.5	-13.1
UK	29	34	34	35	-18.8	-18.8	-22.3
DK	30	36	36	36	-20.3	-20.3	-20.3
CH	43	38	38	38	10.8	10.8	10.8
IE	36	40	40	39	-12.5	-12.5	-9.6
DE	44	42	42	40	4.5	4.5	9.1
FI	47	44	44	42	6.8	6.8	11
IL	38	46	46	43	-21.6	-21.6	-13.7
ES	41	48	48	44	-16.5	-16.5	-6.8
EE	65	50	50	46	23	23	29.2
SI	63	51	52	48	19.4	17.8	24.1
CY	59	53	54	49	10.4	8.7	17.2
AT	63	55	56	51	12.5	11	18.9
NL	39	57	58	53	-46.7	-49.3	-36.4
LT	100	59	60	54	41.2	40.2	46.2
BE	75	61	62	56	18.2	16.8	24.9
SK	55	63	63	58	-15	-15	-5.9
FR	58	65	65	60	-12.8	-12.8	-4.1
MT	22	67	67	62	-210.8	-210.8	-187.6
CZ	71	69	69	65	2.3	2.3	8
PL	93	71	71	67	23.4	23.4	27.7
IT	62	73	73	69	-18.3	-18.3	-11.8
LU	65	74	75	72	-14.2	-15.8	-11.1
HU	61	76	76	74	-25.1	-25.1	-21.8
EL	88	78	78	77	10.9	10.9	12
LV	87	80	80	79	7.7	7.7	8.9
PT	68	82	82	82	-20.4	-20.4	-20.4
HR	92	84	84	85	8.6	8.6	7.5
BG	83	86	86	88	-4.1	-4.1	-6.5
RS	95	88	87	91	7.4	8.4	4.2
RO	96	90	89	94	5.9	6.9	1.7

Appendix E

Table E1 Comparison of real data and the data obtained by time series analysis of road deaths per million inhabitants in 2022 in the EU

Country	Real data	Linear Trend Model	Quadratic Trend Model	Growth Curve Model	% error (Linear)	% error (Quadratic)	% error (Growth)
NO	21	20	26	24	6.5	-21.6	-12.2
SE	22	22	26	25	-1.3	-19.7	-15.1
UK	26	23	27	26	11.2	-4.3	-0.4
DK	26	25	28	27	4.7	-6.8	-3
CH	28	27	29	28	2.1	-5.2	-1.5
IE	31	29	29	29	5.9	5.9	5.9
DE	33	30	30	31	10	10	7
FI	34	32	32	32	7	7	7
IL	37	34	33	33	7.1	9.9	9.9
ES	37	35	34	34	5.6	8.3	8.3
EE	38	37	35	36	1.4	6.8	4.1
SI	40	39	37	37	3.3	8.3	8.3

Table E1 (continuation)

Country	Real data	Linear Trend Model	Quadratic Trend Model	Growth Curve Model	% error (Linear)	% error (Quadratic)	% error (Growth)
CY	41	41	38	38	-0.3	7.1	7.1
AT	41	42	39	40	-1.9	5.4	2.9
NL	42	44	41	41	-5	2.1	2.1
LT	43	46	43	43	-7.6	-0.5	-0.5
BE	45	48	44	45	-7	1.9	-0.3
SK	45	49	46	46	-9.1	-2.5	-2.5
FR	48	51	48	48	-6.1	0.1	0.1
MT	50	53	50	50	-6.2	-0.2	-0.2
CZ	50	54	52	52	-7.8	-3.8	-3.8
PL	50	56	54	54	-11.2	-7.2	-7.2
IT	54	58	56	56	-8	-4.3	-4.3
LU	56	60	59	58	-7.6	-5.8	-4
HU	55	61	61	61	-10.5	-10.5	-10.5
EL	61	63	63	63	-3.8	-3.8	-3.8
LV	60	65	66	65	-7.9	-9.6	-7.9
PT	62	67	68	68	-7.5	-9.2	-9.2
HR	71	68	71	70	4.5	0.3	1.7
BG	78	70	74	73	9.8	4.7	6
RS	83	72	76	76	12.9	8	8
RO	86	73	79	79	14.9	7.9	7.9

