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COMPARATIVE ANALYSIS OF THE VALUES OF TRAFFIC SAFETY INDICATORS RELATING TO PROTECTIVE SYSTEMS IN THE AREA OF POLICE ADMINISTRATION NIS

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Abstract: Each local community has its own specific behavior, so road users behave differently when it comes to prescribed traffic behavior. The monitoring of traffic safety indicators (IBS) in a smaller area creates the possibility of more precise and high-quality monitoring of the situation, identification of key problems, and then more successful management of traffic safety at the local level. The paper first presents the IBS values related to protective systems, which were measured in the area of PU Niš in the period from 2021 to 2025, and then their analysis and mutual comparison was performed, all with the aim of determining the difference in traffic behavior in the specified period. A comparative analysis of IBS in the mentioned period could usefully serve first to define the trend in the use of protective systems, and then for a comparative analysis and exchange of experience between subjects located in the environment of the observed area, all with the aim of better understanding the scope and type of traffic safety problems and more successful management of traffic safety at the local level.

Keywords: indicators, measurement, protection systems, traffic safety

1. INTRODUCTION

Recent research regarding the measurement and assessment of traffic safety levels utilizes the concept of Safety Performance Indicators (SPIs). Safety performance indicators represent any measurement causally linked to traffic accidents and their consequences (ETSC, 2001).

Safety performance indicators serve as a link between the consequences of traffic accidents and measures aimed at reducing these consequences (OECD, 2005). The significance of an indicator can be evaluated based on the strength of its association with the occurrence of a traffic accident or injury (Lipovac, 2008).

Indicators in traffic safety represent a major step forward in traffic safety science and are used for evaluating and monitoring the state of traffic safety. Indicators can be defined as quantitative and qualitative measures derived from a series of observed facts. An indicator can convey a vast amount of information presented in a straightforward manner, which, if properly recognized, can be adequately utilized to improve traffic safety. The particular importance of

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safety performance indicators is reflected in performance monitoring, establishing and tracking trends, predicting issues, evaluating policy impact, benchmarking, etc. (Pešić and Antić, 2012).

Long-term research undoubtedly demonstrates that safety performance indicators (SPIs) are indirect traffic safety measures; that is, they represent parameters that enable the measurement and evaluation of the traffic safety level in a specific area. Over the past decade, traffic safety science has increasingly raised the question of whether it is possible to assess the state of traffic safety using appropriate indicators and metrics that would, in some way, incorporate information not directly linked to traffic accidents and their consequences. Bearing this in mind, safety performance indicators are gaining importance. Monitoring safety performance indicators allows for a clear understanding and precise definition of traffic safety problems, as well as the planning of effective measures to improve traffic safety (Lipovac, 2008).

2. METHODOLOGY FOR MEASURING SAFETY PERFORMANCE INDICATORS RELATED TO RESTRAINT SYSTEMS AND PROTECTIVE EQUIPMENT

As is well known, restraint systems and passive safety systems for road users are designed to mitigate the consequences of traffic accidents. Stated differently, while alcohol and speed can affect both the occurrence and the severity of traffic accidents, the use or non-use of protective equipment primarily influences the consequences of traffic accidents. Passive safety systems include:

- vehicle occupant restraint systems (seat belts, airbags, head restraints),
- child restraint systems (child safety seats, etc.),
- protective equipment for two-wheeler riders (helmets, etc.),
- pedestrian protection systems (pop-up/active hoods, etc.), among others.

The aforementioned systems were developed to protect the most vulnerable parts of the human body. Therefore, monitoring indicators related to protective systems creates an opportunity to identify potential issues and define future actions and measures to increase their usage rate. Given the large number of indicators related to protective systems and the limited scope of this paper, the following sections will present the measurement methodologies for indicators regarding:

- seat belts,
- child safety seats, and
- protective helmets.

2.1. Measurement Methodology and Sample Definition

The measurement methodology and sample size per survey location were established in accordance with the recommendations of the SafetyNet project, funded by the European Commission – Directorate-General for Energy and Transport. Among other objectives, part of the project addresses the development of safety performance indicators based on international best practices (SafetyNet Deliverable 3.1 - State of the Art Report on Road Safety Performance Indicators – Vis et al., 2005), traffic safety indicator theory (SafetyNet Deliverable 3.6 - Road Safety Performance Indicators Theory – Hakkert et al., 2006), and the manual on safety performance indicators (Safetynet Deliverable 3.8 - Road Safety Performance Manual – Hakkert et al.,2007).

The measurement methodology largely depends on what is being measured-specifically, which seat belt safety performance indicators are to be evaluated. This directly influences both the field survey organization and the design of data collection forms. During the measurement

of indicators related to restraint systems, the instructions and guidelines defined by the project "Methods for Monitoring SPIs in Serbia and Their Significance for Strategic Traffic Safety Management" (Vujanić et al., 2013) were strictly followed.

Taking into account the list of key safety performance indicators specified in project [9], as well as the intended scope of this paper, the values of indicators related to restraint systems - as presented in Table 1 - will be detailed below.

Table 1. Safety Performance Indicators Related to Restraint Systems and Protective Equipment

Safety Performance Indicators	Road Category	Number of Observation Sites	Minimum Sample Size
% driver seat belt use in passenger cars and light goods vehicles (up to 3.5t),	- highway - rural road - urban road	1 observation site per road category	500
% front passenger seat belt use in passenger cars and light goods vehicles (up to 3.5t),			384
% rear seat belt use in passenger cars and light goods vehicles (up to 3.5t),			100
% child safety seat use for children up to 3 years of age,			50 (exceptionally 30)
% seat belt or child safety seat use for children aged 4 to 12,			50 (exceptionally 30)
% protective helmet use by moped riders,			50 (exceptionally 30 or 20)
% protective helmet use by motorcyclists,			50 (exceptionally 30 or 20)

When analyzing key safety performance indicators related to restraint systems and protective equipment, measurements are conducted during daylight traffic conditions, depending on the road category, across:

- highways (except for helmet use by moped riders),
- rural roads, and
- urban roads.

Given that measurements are carried out exclusively during daylight hours, it is necessary to conduct them during so-called typical time periods: morning (8:00 AM to 12:00 PM) or afternoon (1:00 PM to 6:00 PM), strictly on specific weekdays (Tuesdays, Wednesdays, or Thursdays). During the measurement of protective system usage, all vehicles-including those with foreign registration plates-were included in the sample; that is, during the random selection of vehicles from the traffic stream, vehicles with foreign license plates were not excluded.

Measurements were conducted at survey locations where vehicles generally move at lower speeds or are stationary (e.g., near intersections, etc.). If, however, a field observer fails to record all necessary data regarding seat belt usage for any reason-particularly due to higher

vehicle speeds-that vehicle is discarded from the sample, and the observer proceeds to record the required data for the very next approaching vehicle.

3. RESEARCH RESULTS AND DISCUSSION

Based on the selected indicators, the defined methodology, and the research sample, this section presents the research results regarding safety performance indicators related to restraint systems and protective equipment. The study was conducted from 2021 to 2025 in the jurisdiction of the Niš Police Directorate. Due to page-limit constraints, the following indicator values related to restraint systems are presented in this paper:

- driver seat belt usage rate in passenger cars and light goods vehicles up to 3.5 t,
- front passenger seat belt usage rate in passenger cars and light goods vehicles up to 3.5 t,
- rear seat belt usage rate in passenger cars and light goods vehicles up to 3.5 t,
- child safety seat usage rate for children up to 3 years of age in passenger cars and light goods vehicles up to 3.5 t,
- seat belt usage rate for children aged 4 to 12 in passenger cars and light goods vehicles up to 3.5 t,
- protective helmet usage rate among moped riders, and
- protective helmet usage rate among motorcyclists..

3.1. Analysis of Seat Belt Usage in Passenger Cars

A comparative analysis of driver seat belt usage in passenger cars and light goods vehicles up to 3.5 t reveals a high and very high level of seat belt use across all observed locations, with values remaining above 94% throughout the period. The lowest value was recorded on rural roads in 2023 at 93.6%, whereas the highest value was recorded on motorways in 2024 at 98.7%. Spatial analysis of average driver seat belt usage indicates that the highest percentage was recorded on motorways at 97.6%, while the lowest was observed on rural roads at 94.9%. Temporal analysis by year shows that no stable trend was established during the observed period; however, there were no significant fluctuations in indicator values (Figure 1).

The average driver seat belt usage rate across all observed locations in the jurisdiction of the Niš Police Directorate was 96.5%, representing a higher percentage compared to the overall indicator value for the Republic of Serbia, which stood at 86.3% during the same period.

A comparative analysis of front passenger seat belt usage in passenger cars and light goods vehicles up to 3.5 t reveals a high and very high level of seat belt use across all observed locations, with values remaining above 90% throughout the period. The lowest value was recorded in urban areas in 2022 at 90.0%, whereas the highest value was recorded on highways in 2025 at 99.4%. Spatial analysis of average front passenger seat belt usage indicates that the highest percentage was recorded on highways at 96.4%, while the lowest was observed on rural roads at 93.2%.

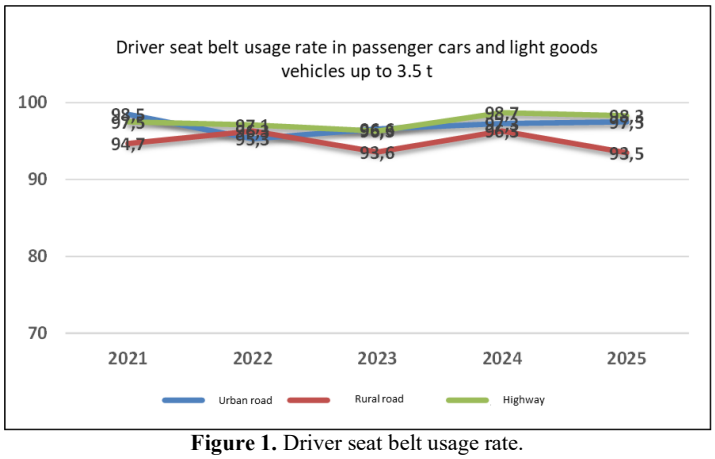


Figure 1. Driver seat belt usage rate.

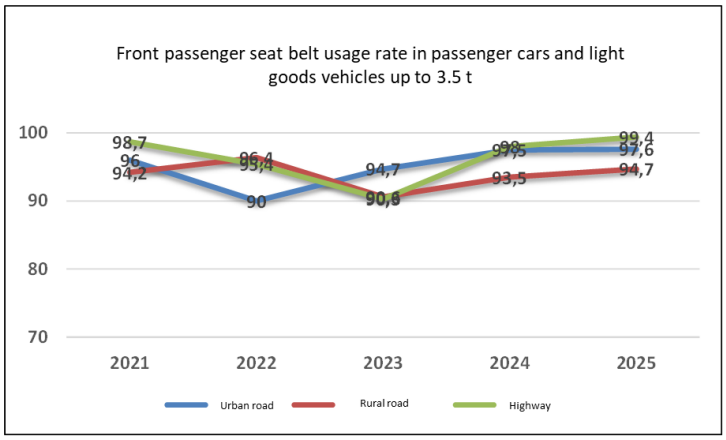


Figure 2. Front passenger seat belt usage rate.

Temporal analysis by year shows that no stable trend was established during the observed period; however, a positive trend has been observed over the last two years, without significant fluctuations in indicator values (Figure 2). It is also noted that the seat belt usage rate among front passengers is slightly lower than that of drivers. The average front passenger seat belt usage rate across all observed locations in the jurisdiction of the Niš Police Directorate during the observed period was 96.4%, which is 3.7 percentage points higher than the national average. Consequently, the Niš Police Directorate ranked 8th, placing it in the upper half of the list.

A comparative analysis of rear seat belt usage in passenger cars and light goods vehicles up to 3.5 t reveals a very low level of seat belt use across all observed locations, with values remaining below 58% throughout the period. The highest value was recorded on highways in 2021 at 58.0%, whereas in other years and at other locations, usage was considerably lower and highly variable. The year 2025 particularly stands out, as a very low value of only 5.1% was recorded on rural roads, highlighting an extremely low level of awareness among drivers and passengers regarding the importance of rear seat belt use. Spatial analysis of average rear seat

belt usage indicates that the highest percentage was recorded on highways at 35.0%, while the lowest was observed on rural roads at 16.7%. Temporal analysis by year shows that no stable trend was established during the observed period and that significant fluctuations in indicator values were present (Figure 3). The average rear seat belt usage rate across all observed locations in the jurisdiction of the Niš Police Directorate was 25.4%. This value is 13.6 percentage points lower than the national average, placing the Niš Police Directorate 18th in the national ranking.

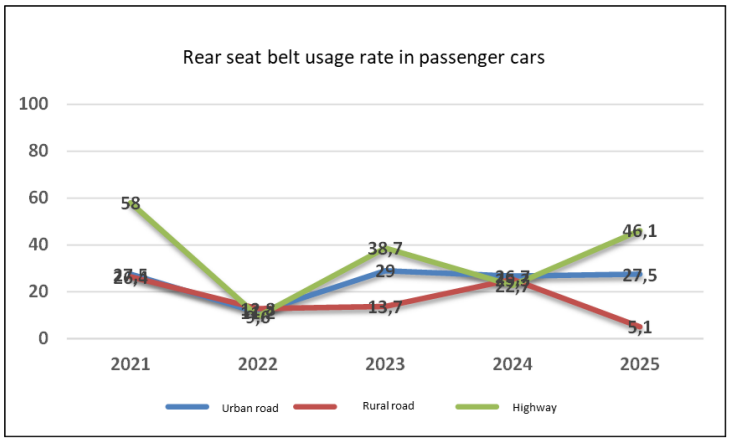


Figure 3. Rear seat belt usage rate.

3.2. Analysis of Child Restraint System and Child Seat Belt Usage

An analysis of the presented data reveals significant differences in the usage rate of child safety seats, both in terms of spatial distribution and temporal trends over the years. The child safety seat usage rate in urban areas recorded an almost steady increase from 57.1% in 2021 to 90.0% in 2025, with the exception of 2023 when a slight decline to 75.0% occurred. A similar trend is observed on rural roads, although a decline in percentage appears twice, specifically in 2023 and 2025. The most pronounced fluctuations were recorded on highways, where the percentage reached 100.0% in 2022, followed by a continuous decline to 76.9% in 2024, before increasing again to 95.8% in 2025. The lowest value was recorded on urban roads in 2021 at 50.0%, whereas the highest value was observed on highways in 2025 at 95.8%, with the average value in the jurisdiction of the Niš Police Directorate standing at 80.5%. Overall, the presented data indicate a marked increase in child safety seat usage during the observed period compared to 2021 (Figure 4).

An analysis of the data regarding the child seat belt usage rate in passenger cars and light goods vehicles up to 3.5 t reveals highly pronounced fluctuations both in terms of spatial distribution and temporal trends over the years. The highest value was recorded on highways in 2024 at 75.0%, while a value of 71.4% was recorded on rural roads in 2023. Conversely, the lowest value was observed on rural roads in 2025 at only 6.6%, with the average value in the jurisdiction of the Niš Police Directorate standing at just 31.4% (Figure 5). Overall, the data indicate marked instability in child seat belt usage, without a clear continuous trend of growth or decline during the observed period. It is particularly noteworthy that very high values were recorded in certain years, whereas in other years the values were exceptionally low. These

results highlight the need for continuous improvement of safety habits and for raising awareness about the importance of the proper use of child restraint systems in vehicles.

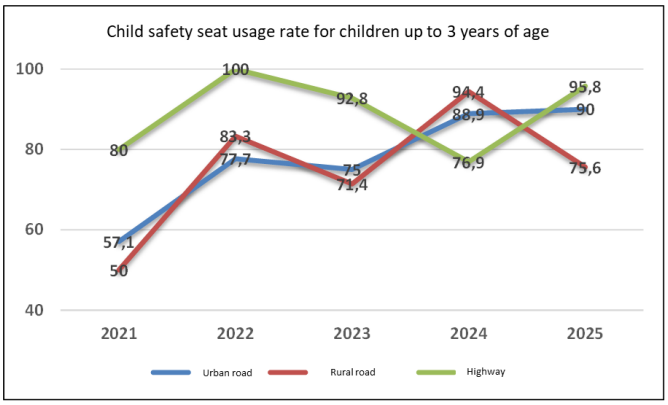


Figure 4. Child safety seat usage rate for children up to 3 years of age.

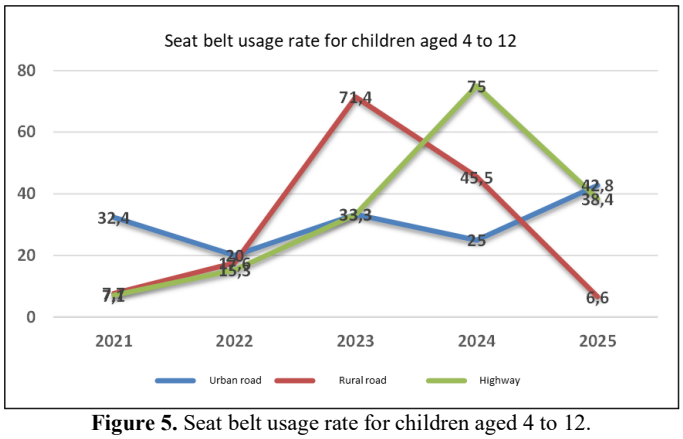


Figure 5. Seat belt usage rate for children aged 4 to 12.

A comparative analysis of the diagrams showing the child safety seat usage rate for children up to 3 years of age and the child restraint system usage rate for children aged 4 to 12 reveals that drivers use child safety seats to a significantly higher extent (80.5%) than they use restraint systems when transporting children (31.4%).

3.3. Analysis of Protective Helmet Usage Among Two-Wheeler Riders

An analysis of the data regarding the protective helmet usage rate among moped riders reveals a decline in percentage in 2025. Specifically, during 2022 and 2023, a very high level of protective helmet usage was achieved, with a value of 100% recorded across all observed locations. On the other hand, in 2024, helmet usage stood at 91.7% in urban areas and 100% on rural roads, whereas in 2025, a drop to 40.0% was recorded in urban areas and 66.6% on rural roads. The lowest value was recorded on urban roads in 2021 at 25.0%, while the average value in the jurisdiction of the Niš Police Directorate was 80.7%. The obtained results indicate

a high level of helmet compliance during most of the observed period, but also a significant drop in usage in 2025, which can be attributed to a substantial increase in the number of mopeds in the Republic of Serbia (Figure 6).

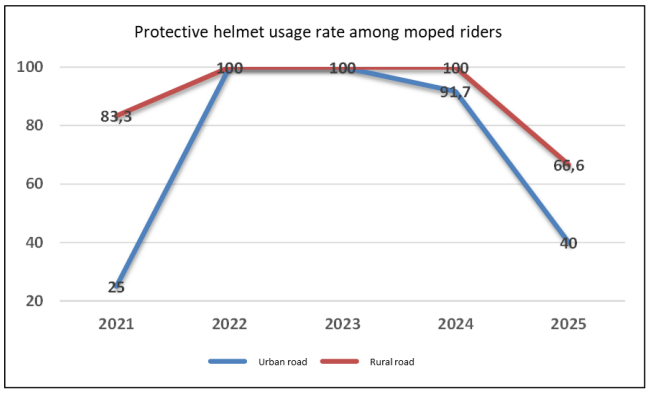


Figure 6. Protective helmet usage rate among moped riders.

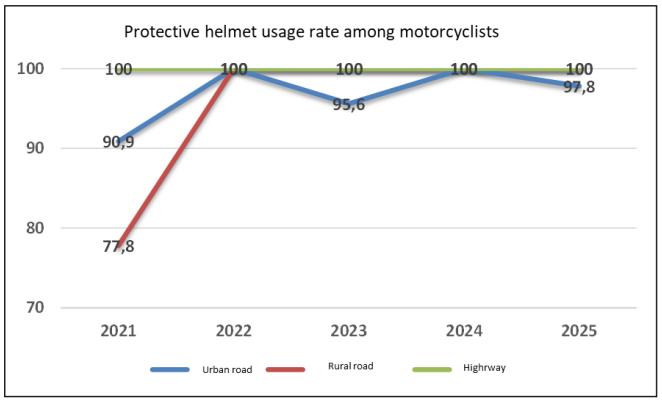


Figure 7. Protective helmet usage rate among motorcyclists.

An analysis of the data regarding the protective helmet usage rate among motorcyclists reveals a very high level of helmet compliance across all observed locations, with recorded values ranging between 90% and 100% in most years. The lowest value was recorded on rural roads in 2021 at 77.8%, whereas full helmet usage (100%) was recorded on highways in the same year. On highways and rural roads, very high values were likewise recorded during 2023 and 2025, indicating a high level of compliance with regulations concerning compulsory protective helmet usage among motorcyclists (Figure 7). The average protective helmet usage rate among motorcyclists in the jurisdiction of the Niš Police Directorate was 97.5%.

4. CONCLUDING REMARKS

The implementation of Safety Performance Indicators (SPIs) in monitoring the road safety status in a specific area is of great importance, as their tracking allows for identifying what, to what extent, and where safety is compromised in traffic. Through proper selection, appropriate

measurement techniques, and, ultimately, correct interpretation of indicator values, road safety issues in a specific area can be identified and targeted for resolution.

At the local community level, recognizing indicators as a means of identifying and monitoring road safety issues is exceptionally important. Indeed, all activities originate at the local level, and ultimately, all road safety measures are implemented there. Therefore, local authorities and entities responsible for road safety must understand the significance of SPIs, select appropriate indicators to track, measure, and evaluate from both professional and scientific perspectives, and incorporate measurement outcomes into their road safety improvement programs.

Road safety performance indicators share a strong correlation with the number of traffic crashes and the severity of their consequences. Consequently, knowledge of SPI values enables the monitoring of conditions and trends in road safety across a given area. Tracking SPIs thus provides excellent support to the road safety management process, enabling the performance evaluation of implemented measures, key stakeholders, and the overall system. This approach to monitoring safety conditions allows for proactive intervention, which remains one of the primary goals of road safety science and practice.

The results of the research conducted on safety performance indicators related to restraint systems in the jurisdiction of the Niš Police Directorate from 2021 to 2025 reveal substantial variation in indicator values and diverging trends. On the one hand, certain indicators demonstrated consistently high values and stable trends throughout the observed period. On the other hand, several indicators exhibited very low values alongside unstable or fluctuating trends. Particularly concerning is the decline in certain indicator values during the final two years of the study. The findings presented in this paper demonstrate that tracking restraint system usage serves as an effective metric for evaluating the performance of entities responsible for road safety.

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