https://doi.org/10.37528/FTTE/9788673954875/TESi.2024.04

The Process of Identifying Road Sections and Locations for Installing Advisory Speed Signs

Dragoslav Kukić, TSRD – Traffic Safety Research Development and AMSS-CMV Research and development centre, Belgrade, kukicdragoslav@gmail.com and kukicdragoslav@cmv.rs

Đorđe Stanisavljević, SAFEGE and TSRD – Traffic Safety Research Development, Belgrade, djordje.stanisavljevic@suezconulting.rs and djordjevr@gmail.com

Miloš Tučić, SAFEGE and TSRD – Traffic Safety Research Development, Belgrade, milos.tucic@suezconsulting.rs and tucic.milos@gmail.com

Ognjen Čuljković, TSRD – Traffic Safety Research Development and AMSS-CMV Istraživačko razvojni centar, Belgrade, ognjen.culjkovic@gmail.com

Abstract: Changes in traffic flow, road profile, and other road elements, as well as changes in weather conditions, often result in dynamic changes in traffic flow, leading to a decrease in the level of service on roads. To improve traffic safety and better manage speeds on sections with specific technical and operational characteristics, as well as frequent changes in weather conditions, it is desirable to timely inform drivers about the necessary speed reduction. This type of information provision on roads can be achieved using advisory speed signs. When choosing an advisory speed sign, preference can be given to the so-called "smart (autonomous) traffic sign" for advisory speed, which addresses the "static" choice of advisory speed present in conventional traffic signs. The selection of locations for placing advisory speed signs plays a crucial role from the perspective of driver acceptance of the given information, which is challenging in situations where the credibility of the limited or advisory speed is lacking. Locations where it is desirable to place advisory speed signs are those that stand out due to their specific characteristics, which can be static (road characteristics) or dynamic (weather conditions or traffic flow conditions). This paper presents the procedure and process of identifying locations on roads where the placement of a smart advisory speed sign would have the most positive effect on the dynamic characteristics of traffic and traffic safety.

Key words: advisory speed, "smart traffic sign," technical and operational characteristics, weather conditions

1 INTRODUCTION

Effective traffic management and road safety are critical components of modern transportation systems. One innovative approach to enhancing these aspects is the strategic placement of advisory speed signs. These signs provide drivers with advisory speeds helping to reduce accidents and improve traffic flow. The process of identifying road sections and locations for placing advisory speed signs is a comprehensive and data-driven approach to enhancing road safety and traffic management. In this paper, the

primary focus is on determining the macro-locations for placing advisory speed signs (road sections and segments).

However, determining the micro-location, i.e., the exact position of the sign, requires consideration of other aspects. The paper will also discuss a smart advisory speed sign that independently determines the safest recommended speed for current conditions, based on changes in weather, road characteristics and traffic flow.

When determining the micro-location, it is necessary to take into account the road alignment and cross-sectional profile (assess the road's physical characteristics, such as curves, slopes, and surface conditions) and also the time required to detect and recognize the sign, as well as the time needed for the driver to make a decision and react [1]. Areas with sharp curves, intersections, or other complex road features often require lower speeds than the mandatory speed limit. In these locations, advisory speed limits can have a significant impact on improving road safety.

Advisory speed signs should be placed to provide adequate perception-reaction time. When installing advisory speed signs, it is also important to consider the vehicle's speed and the distance before which the driver needs to be warned about the recommended speed, ensuring the driver has enough time to adjust the vehicle's speed. One of models suggest that advisory speed signs should be placed farther from the start of alignment changes at higher speeds to provide adequate reaction time, while closer placement is recommended when advisory speeds are within 30km/h of the approach speed [2].

2 SMART TRAFFIC SIGN FOR ADVISORY SPEED

A smart traffic sign for advisory speed can be defined as a complex system of elements that independently collects data on current road conditions, weather, and traffic flow. It processes the collected data and, using fuzzy logic, autonomously determines the safest vehicle speed for the current conditions, adhering to the latest scientific achievements and industry standards [3]. Fuzzy logic is one technique that is an effective way to deal with qualitative terms, linguistic vagueness, and human intervention [4]. The evolution of fuzzy logic controlling systems came to the more complex, more adaptive, and more intelligent frameworks that allow not only the use of fuzzy logic but also the combination with real-time data and optimization using, for example, genetic algorithms and neural networks [5].

A smart traffic sign for advisory speed continuously monitors the surrounding conditions (road surface state, weather conditions, and traffic flow) using its associated devices (sensors). It independently analyses the data obtained from the sensors, determines the safest speed for the current conditions, and locally informs traffic participants of the safest speed they can travel under the current conditions via a variable message sign, without central control or human assistance.

Safe traffic operations and driver behavior during rainfall, fog, or other adverse weather conditions present a highly complex issue. In such situations, the amount of information a driver receives from the environment decreases, making it difficult for the driver to determine and adjust their speed appropriately. By leveraging modern technology and real-time data, smart traffic signs for advisory speed provide a dynamic solution that can adapt to changing conditions, ultimately leading to safer and more efficient roads.

When adverse driving conditions arise (e.g., heavy rain combined with reduced visibility, strong winds, and traffic congestion), the smart traffic sign autonomously calculates and reduces the recommended speed to the safest speed for the current driving conditions. Then, when driving conditions improve, the smart traffic sign increases the recommended speed value in accordance with the current traffic conditions.

Figure 1. Smart Traffic Sign for Advisory Speed

A smart traffic sign is most effective on road sections where driving conditions frequently change (such as fog, rain, ice, strong wind gusts, frequent traffic jams, etc.). These are primarily high-risk sections where the most common types of traffic accidents are head-on collisions and vehicles running off the road. Examples include sections in gorges and valleys, viaducts, and roads alongside rivers. In urban areas, these include sections on bridges, boulevards, or streets near rivers [6].

3 DETERMINING LOCATIONS FOR INSTALLING ADVISORY SPEED SIGNS

Whether an advisory speed sign will fulfil its purpose and its goal depends on the places and sections where it will be installed. The primary effects of an advisory speed sign are reflected in the improvement of traffic safety by reducing the number of traffic accidents which occur due to vehicles traveling at speeds not adapted to current conditions. Changes in weather conditions such as rain, fog, sleet, snow, etc., not only reduce visibility but also affect the road surface characteristics, leading to a decrease in the friction coefficient. Combined with traffic congestion, these factors create extremely unfavourable driving conditions.

When determining locations for installing advisory speed signs, it is necessary to consider available data on traffic accidents caused by poor driving conditions, risk mapping data, analysis of hazardous locations (black spots), traffic load data analysis, weather conditions prevailing on the section throughout the year, and expected road conditions based on available data. The process of identifying road sections and locations for installing advisory speed signs is based on specific analyses and criteria. The analyses that can be applied for selecting locations where the advisory speed sign will be installed include the following analyses.

Risk Mapping based on Road Assessment Program (Safety Characteristics Analysis): Evaluating the safety features of the road. Risk mapping based on the analysis of road safety characteristics is conducted using specialized vehicles equipped with GPS devices and cameras. The recorded road characteristics are then analysed and evaluated in digital form. When selecting locations for the implementation of advisory speed signs that recommend speed limits, priority is given to sections rated with the lowest values, which are assigned specific weighting factors in the final calculation. The reason for prioritizing these sections is that they possess certain unsafe characteristics that could lead to traffic accidents.

Risk Mapping based on Traffic Accident Data: Analysing traffic accidents and their consequences. Risk mapping based on data about traffic accidents and their consequences on road sections is conducted based on two types of risks:

- Collective risk, which includes the risk of casualties relative to the length of the observed road section.
- Individual risk, which includes the risk of casualties relative to the number of vehicle kilometres travelled on the observed road section.

Given the importance of this type of risk mapping in identifying parts of the road network with an increased risk of traffic accidents based on historical data about accidents and their consequences, it is crucial to include this analysis when deciding on which road sections to implement advisory speed signs.

Analysis of Hazardous Locations ("Black Spots"): Identifying areas with a high frequency of accidents. The identification of hazardous locations (black spots) belongs to the so-called reactive method of traffic safety improvement. This method involves identifying and addressing problems only after an undesirable event, such as a traffic accident, has occurred. Given the importance of this tool in identifying the most critical locations on the road and street network based on historical data about traffic accidents and their consequences, it is necessary to include this analysis when deciding on which road sections to implement advisory speed signs.

Analysis of Locations Recognized by Existing Software Solutions: For example, used by traffic police to direct speed control activities or other software used by road authorities or road safety agencies.

Traffic Load Data Analysis for the Last 3 Years: Assessing traffic volume and patterns. Many factors can influence the occurrence of traffic accidents, including vehicle flow, traffic density, traffic flow structure, road section length, geometric road characteristics, access control, pavement condition, lighting, and more. Traffic flow is most commonly expressed as the Average Annual Daily Traffic (AADT), which is a key indicator of road network load. It is calculated as the ratio of the total vehicle flow at a given location over a year to the number of days in the year. Many studies indicate that the number and consequences of traffic accidents depend on AADT, which is why it is important to consider this data when selecting locations for the installation of advisory speed signs.

Weather Conditions Analysis: Evaluating wind, rain, fog, etc., throughout the year (monthly, seasonally) and expected road conditions (ice, frost) based on available data. The impact of meteorological or weather conditions on traffic safety has been studied for many years worldwide.

Research indicates that during adverse weather conditions, friction between tires and the road surface decreases, visibility is reduced, and vehicle handling becomes more difficult. Studies also show that the number of traffic accidents increases during precipitation, especially at the onset of rain. Scandinavian studies have shown that unexpected snowfall, the first autumn snow, and precipitation after long dry periods significantly increase the risk of accidents, particularly those involving casualties. Due to the influence of meteorological conditions on the occurrence of traffic accidents, the implementation of advisory speed signs that can provide timely information on the optimal (safe) speed for given conditions based on collected, processed, and analysed environmental data is crucial. This would enable quality and timely driver information about the advisory speed under current weather and other hydrometeorological conditions prevailing on the road.

Road Infrastructure and Equipment Analysis: Considering the presence of elements for easy installation of smart traffic signs (sufficient shoulder/sidewalk width, presence of guardrails, etc.). When selecting micro-locations for the installation of smart traffic signs recommending speed limits on specific road sections, it is essential to analyse the presence of elements that facilitate the easy installation of these signs. This serves as an additional criterion for choosing locations for smart traffic signs, aiding in the precise positioning of the devices on the road section.

Energy Efficiency Analysis: Assessing the availability of electrical power or the possibility of using solar panels in areas without electrical power. Energy efficiency analysis is an additional criterion considered when selecting micro-locations for the installation of smart traffic signs for advisory speed on specific road sections.

To calculate the final score for selecting locations for the implementation of advisory speed signs, it is first necessary to assign appropriate weight coefficients to the defined indicators (criteria), which are then used to multiply the obtained scores of the criteria. Indicators (criteria) are results from the above-mentioned analyses. Based on the obtained final score of the section according to all defined criteria for selecting locations for the implementation of advisory speed signs, ranking needs to be performed to determine which road sections should first implement advisory speed sign.

The previously described analyses determine the macro-locations, i.e., road sections, where the placement of advisory speed signs would have the greatest effect. To determine the micro-locations, additional analyses are needed, including the examination of the road alignment and cross-sectional profile, to identify the exact positions for placing advisory speed signs. Proper placement of advisory speed signs is crucial for giving drivers adequate time to respond to changes in road alignment.

When determining the micro-location for placing signs, it is also necessary to consider the vehicle’s speed and the time required for the driver to adjust the vehicle’s speed. Advance placement of warning signs should be adjusted based on approach speed and the appropriate speed for negotiating hazards, with higher speeds requiring signs to be placed farther from the hazard [7]. Advisory speed signs should be placed considering drivers' visual characteristics and operating speeds, with specific thresholds for speed differentials based on curve radius [8].

4 CONCLUSIONS

By following this structured approach, advisory speed signs can be strategically placed to maximize their positive impact on road safety and traffic management. Determining advisory speeds is a multifaceted process that requires careful analysis of road characteristics, traffic patterns, and environmental conditions. By setting appropriate advisory speeds, road authorities can significantly reduce the risk of accidents.

To fulfill its purpose and achieve the greatest effects, advisory speed signs should be installed on sections where there is a real need. When determining locations for installing advisory speed signs, it is necessary to consider available data on traffic accidents caused by poor driving conditions, risk mapping data, analysis of hazardous locations (black spots), analysis of locations used by traffic police to monitor compliance with prescribed speed limits, analysis of traffic load data, analysis of weather conditions prevailing on the section throughout the year, and expected road conditions based on available data.

As technology advances, the use of smart traffic management systems will likely play an increasingly important role in this process. Implementing smart traffic signs for advisory speed that adjusts based on weather conditions, road and traffic conditions, road safety can be further enhanced by providing real-time information and recommendations to drivers. By conducting the aforementioned analyses, it is possible to identify locations where it is optimal to install smart traffic signs that generate advisory speeds based on collected parameters for current conditions.

REFERENCES

[1] U.S. Department of Transportation. Federal Highway Administration. (2023). Manual on Uniform Traffic Control Devices for Streets and Highways. 11th Edition.

[2] Hawkins, H., Brimley, B., & Carlson, P. (2016). Updated Model for Advance Placement of Turn and Curve Warning Signs. *Transportation Research Record*, 2555, 111 – 119. https://doi.org/10.3141/2555-15.

[3] Kukic, D., Stanisavljevic, Dj., Nojkovic, D., Tucic, M. 2022. Application of the "Fuzzy logic" in the decision-making process related to vehicle advisory speed. In proc. XIII Conference on traffic Engineering Techniques TESi. doi: https://doi.org/10.37528/FTTE/9788673954585/TESi.2022.042

[4] Quddus, M., Noland, R., & Ochieng, W. (2006). A High Accuracy Fuzzy Logic Based Map Matching Algorithm for Road Transport. Journal of Intelligent Transportation Systems, 10, 103 – 115. https://doi.org/10.1080/15472450600793560.

[5] Koukol, M., Zajíčková, L., Marek, L., & Tucek, P. (2015). Fuzzy Logic in Traffic Engineering: A Review on Signal Control. Mathematical Problems in Engineering, 2015, 1-14. https://doi.org/10.1155/2015/979160.

[6] Kukic, D., Stanisavljevic, Dj., Nojkovic, D., Tucic, M. 2023. Methodology for determining locations for installation of smart traffic signs for advisory speed. In proc. XVIII International conference road safety in local communities.

[7] Hawkins, H., Brimley, B., & Carlson, P. (2016). Updated Model for Advance Placement of Turn and Curve Warning Signs. *Transportation Research Record*, 2555, 111 – 119. https://doi.org/10.3141/2555-15.

[8] Yu-long, H. (2011). Curve advisory speed signs setting for freeway at mountain area. *Journal of Chang'an University*.

SUMMARY

Proces identifikacije deonica i lokacija na putevima za postavljanje saobraćajnih znakova za preporučenu brzinu

Rezime: Promene u saobraćajnom toku, putnom profilu i drugim putnim elementima, kao i promene u vremenskim uslovima, najčešće rezultiraju promenama dinamičkih uslova u saobraćajnom toku, koji zatim dovode do pada nivoa usluge na putevima. U cilju poboljšanja bezbednosti saobraćaja i kvalitetnijem upravljanju brzinama na deonicama gde su prisutne specifične tehničko eksploatacione karakteristike u odnosu na trasu pružanja puta, kao i u odnosu na česte promene vremenskih uslova u saobraćaju, poželjno je pravovremeno informisati vozače o potrebnom smanjenju brzine. Ovakav vid pružanja informacija na putevima može se postići primenom saobraćajnih znakova za preporučenu brzinu kretanja. U slučaju izbora saobraćajnog znaka za preporučenu brzinu kretanja, prednost možemo dati izboru tzv. „pametnog (autonomnog) saobraćajnog znaka" za preporučenu brzinu kretanja, čijom primenom rešavamo „statičan" izbor preporučene brzine, što je prisutno kod konvencionalnih saobraćajnih znakova. Izbor lokacija za postavljanje saobraćajnih znakova za preporučenu brzinu ima ključnu ulogu iz perspektive prihvatanja date informacije od strane vozača, što je otežano u situacijama kada ne postoji kredibilitet ograničene ili preporučene brzine kretanja. Mesta na kojima je poželjno postaviti saobraćajne znakove za preporučenu brzinu kretanja su mesta koja se ističu po svojim specifičnim karakteristikama, koje mogu biti statične (karakteristike puta) ili dinamičke (meteorološki uslovi ili uslovi u saobraćajnom toku). U radu je predstavljen postupak i proces identifikacije lokacija na putevima na kojima bi izbor postavljanja pametnog saobraćajnog znaka za preporučenu brzinu imao najveći pozitivan efekat na dinamičke karakteristike saobraćaja i bezbednost u saobraćaju.

Ključne reči: preporučena brzina, „pametni saobraćajni znak", tehničko eksploatacione karakteristike, meteorološki uslovi