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ENHANCEMENT OF ROAD SAFETY: A PROPOSED REVISION OF THE REGULATIONS FOR THE DESIGN OF PUBLIC ROADS IN CROATIA

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Abstract

The current Croatian Regulation for the design of highways and rural roads is outdated, dating back to 2001. The regulation is based on outdated assumptions that no longer reflect the prevailing traffic conditions. Over the past two decades, there has been a significant increase in the number of vehicles on Croatian roads, accompanied by a corresponding rise in vehicle dimensions and weight. This evolving traffic landscape necessitates a reassessment of the fundamental premises upon which the regulation is predicated and a consequent revision of its provisions. To address this need, a comprehensive analysis of neighbouring countries' regulations and guidelines, including Slovenia, Austria and Germany, was undertaken. This comparative analysis revealed a common approach to classifying roads based on their intended function and maximum permitted speed. Building upon this insight, a proposal for design classes of the national network is presented. Highways are divided into three classes (AC-1, AC-2, AC-3) according to their maximum permitted speed, while rural roads are categorized into five classes (CIN-1 to CIN-5) based on their intended function and maximum permitted speed. For each design class, a distinctive cross-sectional profile appearance is defined, encompassing geometric elements such as traffic lane, shoulder, and median. These proposed profile appearances are tailored to the specific requirements of each design class, ensuring that the road infrastructure aligns with the expected traffic volumes and characteristics. The potential impact of adopting design classes on the existing built network of state roads is thoroughly examined. The analysis reveals that the application of design classes can significantly enhance traffic safety without necessitating extensive reconstruction of existing road infrastructure. In conclusion, the proposed revision of the Croatian Regulation adopts a modern approach that aligns with international standards and best practices. The introduction of design classes, along with the corresponding typical cross-section profile, will contribute to a safer and more efficient road network across Croatia.

Keywords: rural roads and highways design classes, regulations, guidelines, typical cross sections

1 Introduction

The progress of the automotive industry in recent decades has led to significant changes in both the dimensions and performance of personal vehicles. Various factors are contributing to the gradual increase in the size of cars, with a focus on improved safety, consumer demand for more comfortable vehicles and the addition of technological features. Increasing safety standards are one of the main reasons for the growth in vehicle dimensions. Manufacturers are continuously improving safety features to ensure greater passenger protection in the event of an accident. The installation of advanced safety systems, such as multiple air-

bags and the reinforcement of the body structure, requires more space. On the other hand, consumer demand for larger and more comfortable vehicles is also influencing the increase in dimensions. Lifestyle trends such as larger families or the need for more luggage space encourage manufacturers to produce more spacious vehicles that meet these needs. The addition of technological features is also contributing to the growth in dimensions. Advanced safety systems, infotainment systems and driver assistance systems require additional space for the installation of components.
In Europe, the increasing sales of SUVs continues to have an impact on the average size of new vehicles. Research [1] has shown that the average dimensions of newly sold vehicles increase by around 1 cm every two years, while the mass increases by around 8.5 kg annually. This data clearly demonstrates the trend of increasing vehicle dimensions over the last decade.
It is important to point out that these increasing dimensions are coming up against infrastructural limits. Half of the newly registered vehicles in Europe are already too large for existing parking spaces, while the maximum permissible width of road vehicles has not changed since the mid-1990s.

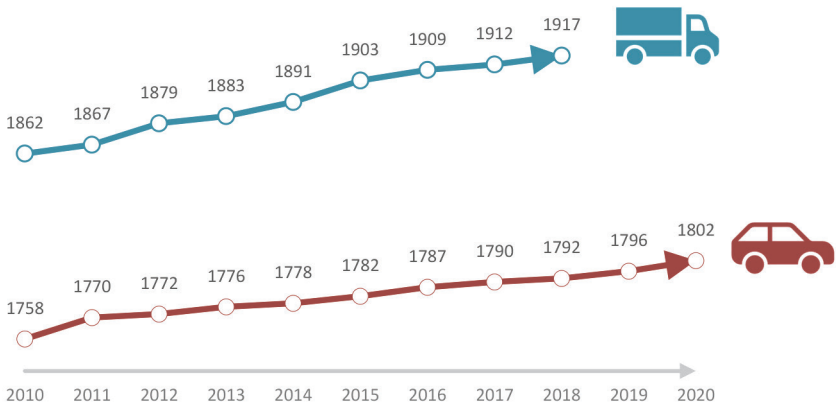

Figure 1 Average width of personal car and light commercial vehicle sold in Europe (2010 – 2020) [2]

To ensure road safety, prevent damage to roads, bridges and tunnels and promote fair competition in road transport in Europe, heavy goods vehicles, including trucks, buses, coaches and articulated vehicles, must comply with certain weight and dimension requirements. These rules are laid down in Council Directive 96/53/EC, commonly referred to as the Weights and Dimensions Directive. This directive makes it possible to establish standardised rules for maximum dimensions in the Member States [3].
In addition to the increase in dimensions, the performance of vehicles has also changed significantly over the last ten years. Technological and design advances have enabled vehicles to achieve greater performance, efficiency, and comfort. Improvements in suspension, steering and brakes have also contributed to better vehicle performance. Advanced technologies such as electronically controlled suspensions, stability control systems and advanced braking systems improve control and driving safety.
The current Croatian regulation dates back to 2001 [4], with minimal amendments made in 2022. It is based on a work study from 1993, which in turn is based on almost identical fundamental principles as the 1981 regulation [5]. The basic settings in the existing regulation, such as the method for determining the road category, determining the design speed, deter-

mining the typical road cross-section and calculating the cross slope of the road in curves and the stopping sight distance, date back to the last century and it is necessary to update them in order to ensure the safety and functionality of road traffic in the future.
The implementation of new technological solutions in the automotive industry, the improvement of vehicle and infrastructure safety, sustainability and environmental protection are some of the reasons for updating the regulations. Considering the scope of the regulations, this paper focuses on changing the way the basic measures and basic elements of the route are determined by project classes, following the trend that countries in the neighbourhood have started to apply.

2 Review of Regulations and Guidelines

Building safe, efficient, and sustainable roads requires careful planning and design. Various factors such as user needs, traffic flow and environmental impact must be considered. An important aspect is the choice of the right design elements, which are often influenced by road categorisation and design classes.
Currently, the Croatian regulation [4] categorize roads into six categories, ranging from highways to local roads, based on factors such as traffic volume and socio-economic importance (Table 1). This category forms the basis for the design speed and other important elements such as curves, gradients, and carriageway width. However, the current system allows for some flexibility in the interpretation of the regulations, resulting in roads with similar characteristics but different cross-sections.

Table 1 Road categorisation [4]

Road category	Socio-economic importance	Type of traffic	Traffic volume [veh/day]	Connectivity	Mean travel distance [km]	Cross-section type
Highway	State	Motor vehicle	>14.000	Interstate and State	>100	A-a, A-b, A-c, A-d
1st cat.	State	Motor vehicle	>12.000	Interstate and State-regional	50-100	1-b, 1-c, 1-d, 1-e
2nd cat.	State	Motor vehicle/ Mixed traffic	7.000-12.000	State and County	20-50	2-b, 2-c, 2-d, 2-e, 2-f
3rd cat.	State/ County	Mixed traffic	3.000-7.000	Inter-municipal	5-50	3-d, 3-e, 3-f, 3-g
4th cat.	County/ Local	Mixed traffic	1.000-3.000	Municipal	5-20	4-e, 4-f, 4-g, 4-h
5th cat.	Local	Mixed traffic	<1.000	Municipal-local	<5	5-f, 5-g, 5-h

The Austrian guidelines [6, 7] offer a different perspective. Their categorisation assigns specific characteristics and requirements to road sections based on their function, influencing elements such as curve radii, gradients and entry speeds. In urban areas, further distinctions are made based on connectivity, accessibility and residential needs.
The German guidelines [8-10], on the other hand, prioritise the function of a road within the network. They classify roads into three main groups (highways, rural roads and urban roads) and provide separate design guidelines for each group. Within each group, additional design classes define different road characteristics.

The Slovenian regulation [11] offers a hybrid approach where roads are classified by function and type, while the design speed is used to determine the geometric elements. However, the carriageway width remains the same within each category, regardless of location.
The comparison of these approaches shows clear differences in content, concept and solution methods. In particular, the German guidelines for highways and rural roads use a novel design approach in which all elements are defined by a "design class" rather than design speed. This assumes that drivers will recognize the road type and adjust their speed accordingly. However, even in this system, some elements are still bound by the design speed limits.
Ultimately, the optimal approach depends on various factors, including traffic patterns, landscape characteristics and budget constraints. Each method has its advantages and disadvantages, and careful consideration is crucial for creating safe and efficient road networks.

3 Proposal

Roads, the lifeblood of our infrastructure, are constantly adapting to changing needs. From construction to modernization and even complete rebuilding, their design elements are guided by contemporary legislation, prioritizing safety and accessibility for all users.
Regulations and guidelines are the foundation for reliable road design. They ensure consistency and functionality and create a standardised experience for users on similar roads. To achieve this, roads are categorised based on key factors such as type (highway, street, etc.), location (urban, rural) and jurisdiction. These factors collectively reflect the importance of the road for spatial planning, traffic flow and environmental impact.
Reconstruction of existing roads serves several purposes: extending their lifespan, increasing capacity, updating the design (especially the alignment), adding lanes and installing specialised infrastructure for pedestrians and cyclists. Regardless of the reason, the same principle applies to reconstruction as to new construction: adapting to current regulations to ensure safety, accessibility and consistency.
However, the regulations themselves can evolve. In the past, amendments to road design regulations, particularly those affecting basic elements such as alignment or cross-section, only affected the reconstruction of existing infrastructure.
Recent trends in road design highlight the selection of design elements based on a specific "design class". This ensures the uniformity of roads with similar functions and traffic volumes.
Therefore, highways are divided into three design classes (AC-1, AC-2 and AC-3) based on the maximum permitted speed. Rural roads are categorised into five design classes (CIN-1 to CIN-5) based on their function and maximum permitted speed. For each design class (Table 2), there are specific guidelines, including the road type, which is defined by terrain restrictions and typical cross-section. These details ensure consistency and safety on similar roads and provide a predictable and comfortable experience for all users.
Each design class has a specific cross-sectional pattern that is determined by the width of the carriageway, shoulder and median widths. These details provide a clear framework for designing roads that meet their specific requirements while maintaining consistency within their class. The components of typical cross-section profiles are shown in Table 3.

Table 2 Proposed design classes

Design class	Max permitted speed [km/h]	Traffic type	Road type			Cross-section type
			Plain terrain	Hilly terrain	Mountain terrain	
Highways (AC)						
AC-1	130	Motor vehicle	Highway		-	TPP-29
AC-2	110	Motor vehicle	-	Highway		TPP-28
AC-3	90	Motor vehicle	-	-	Highway	TPP-27
Rural roads (CIN)						
CIN-1	110	Motor vehicle	State Road*	-	-	TPP-22
CIN-2	90	Motor vehicle / Mixed	State Road	State Road*		TPP-21.5/ TPP-11
CIN-3	70	Mixed	County Road	State Road	-	TPP-10,5
CIN-4	50	Mixed	Local Road	County Road	State Road	TPP-8.5
CIN-5	40	Mixed	-	Local Road	County/ Local Road	TPP-8

Table 3 Typical cross-section dimensions

Design class	Cross-section type	Traffic lane [m]	Curb lane [m]	Shoulder [m]	Median [m]	Emergency lane [m]
Highways (AC)						
AC-1	TPP-29 / TPP-36	3.75	0.50	1.50	4.00	2.50
AC-2	TPP-28 / TPP-35	3.50	0.50	1.50	4.00	2.50
AC-3	TPP-27 / TPP-34	3.50	0.50	1.50	3.00	2.50
Rural roads (CIN)						
CIN-1	TPP-22	3.50	0.50	1.50	3.00	-
CIN-2	TPP-11 / TPP-21,5	3.50	0.50	1.50	2.50	-
CIN-3	TPP-10,5	3.25	0.50	1.50	-	-
CIN-4	TPP-8,5	3.00	0.25	1.00	-	-
CIN-5	TPP-8	2.75	0.25	1.00	-	-

This evolving approach to regulating road design strikes a balance between the need for safety and uniformity and the ability to adapt to individual road requirements. By categorising roads based on function and traffic importance, regulations can provide a flexible framework for building and rebuilding a safe and efficient road network that meets our ever-changing needs.

4 Consequences

The new proposal to define road design elements by design classes aims to adapt carriageway widths to the type of road and the maximum permitted speed. A study was carried out to assess the impact of the introduction of design classes on the existing infrastructure.
The study analysed the carriageway widths of existing roads and determined the necessary increase in lane width increase during reconstruction. The data on carriageway widths and speed limits on state roads were obtained from the Croatian road database from 2014. The analysis covered 6,500 kilometres of one carriageway two-lane state roads.
According to the current Regulation [4], state roads belong to the first three categories and can have a design speed of 50 to 100 km/h, depending on the speed limit. The corresponding typical cross-section is selected based on the chosen design speed.

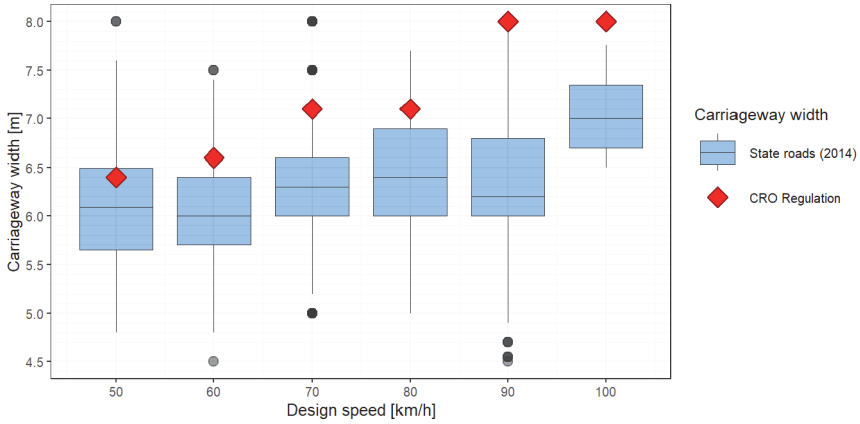

Figure 2 Distribution of carriageway widths of state roads according to design speed compared to prescribed by Croatian regulation

The analysis of existing state roads by design speed (Figure 2) has shown that carriageway widths vary widely, ranging from 4.50 to 8.00 metres. Median carriageway widths show that the carriageway width increases with the design speed but remains smaller than prescribed in the current regulation. This leads to the conclusion that the carriageway width must be widened to the prescribed value when renovating existing sections of state road.
A similar conclusion can be drawn from analysing the impact of the selection of design elements by design classes. The proposed carriageway widths are slightly wider than specified in the current regulation.
For design class CIN-4 (corresponding to a design speed of 50 km/h), the proposed carriageway width is 6.50 m, which is 10 cm wider than in the current regulation. For design class CIN-3 (corresponding to a design speed of 60 and 70 km/h), the carriageway width is 7.50 m, which is 40 and 90 cm wider than the current regulation. For design classes CIN-2 and CIN-1 (for design speeds of 80 km/h and above), the carriageway width is 8.00 m, which corresponds to the current regulation.
The introduction of the design classes will only have a limited impact on the reconstruction of the existing road infrastructure. The proposed carriageway widths are generally the same as the current regulation, with some minor increases for certain design classes. These increases are necessary to ensure safety and improve traffic flow on high-speed roads.

The difference between the measured carriageway widths of state roads and the carriageway widths prescribed in the current Croatian regulation and the proposal of the new regulation, described as the proportion of the road length to the total road length, is presented in Figure 3.

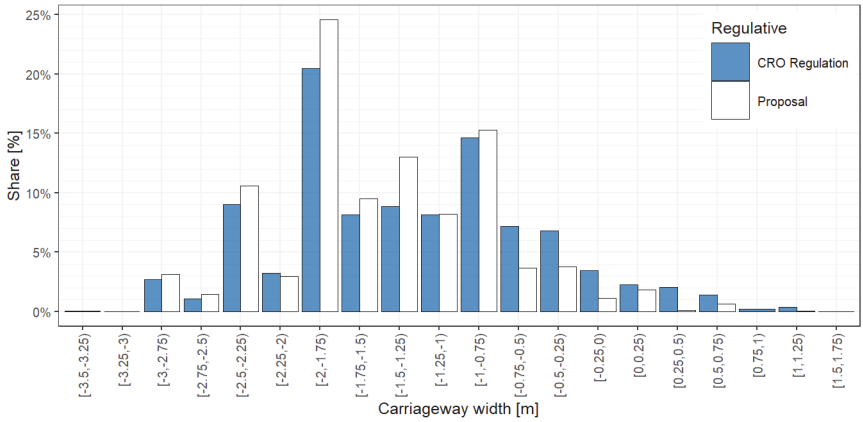

Figure 3 The required width of the carriageway extension by share of state roads

5 Conclusion

The existing Croatian regulation on the design of highways and rural roads needs to be updated to reflect advances in the automotive industry, stricter safety standards and environmental concerns. The proposed new regulation introduces one major change: the selection of design elements based on “design classes”.

In contrast to the current regulation, which is based on design speed, the design elements in the design classes will be clearly defined based on the intended function of a road and terrain constraints. To achieve a uniform appearance for roads with a similar purpose, each design class will be assigned a unique typical cross-section.

The new regulation applies to both new construction and reconstruction of existing roads. An analysis of existing lane widths on state roads revealed that a significant proportion of the road network will need to be reconstructed to comply with the current regulation.

The implementation of the proposed new regulation on existing infrastructure will have similar consequences to the application of the current regulation. Using carriageway width as an example, the average increase in the overall state road network is only 20 centimetres to comply with the new design classification is only 20 centimetres.

This minimal impact shows that the new regulation enables a smooth transition to modern, safe and environmentally sustainable roads without major disruption to existing infrastructure. By introducing design classes, we can ensure a future where our roads meet the needs of both users and the environment.

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