XVII International Symposium
"ROAD ACCIDENTS PREVENTION 2026"
Novi Sad, Serbia, 14th and 15th October 2026.

https://doi.org/10.68515/RAP.2026.17.8

PROPOSAL FOR A REVISED SLOVENIAN TECHNICAL SPECIFICATION FOR TRAFFIC CALMING AT UNSIGNALIZED AT-GRADE INTERSECTIONS

Ivana Prelovac[a*], Laura Brigita Parežnik[a], Marko Renčelj[a]
[a] Faculty of Civil Engineering, Transportation Engineering and Architecture, University of Maribor, Smetanova ulica 17, 2000 Maribor, Slovenia
Ivana Prelovac: ivana.prelovac@um.si, orcid.org/ 0009-0009-0384-1917
Laura Brigita Parežnik: laura.pareznik@um.si, orcid.org/0009-0007-2423-0491
Marko Renčelj: marko.rencelj@um.si, orcid.org/0000-0003-3739-5264

Abstract: Unsignalized at-grade intersections represent an important part of the road network, where the large number of conflict points, diverse traffic manoeuvres, and inappropriate vehicle speeds frequently lead to traffic accidents. Effective planning of traffic calming devices and measures therefore plays a key role in improving the road safety of all road users. In Slovenia, the planning of traffic calming measures at unsignalized at-grade intersections is regulated by the technical specification TSC 02.203:2009, which, due to developments in traffic planning, the introduction of new measures, modern design approaches, and seventeen years since its publication, requires revision. The aim of this paper is to present a proposal for a revised Slovenian technical specification. A systematic review of national and international scientific literature, technical guidelines, standards, and examples of good practice was conducted. Based on this review, contemporary approaches, new measures, and improvements to existing solutions were identified, forming the basis for the proposed revised technical specification. The proposal includes new planning principles, enhancements to existing measures, and the introduction of new infrastructure solutions. The proposed revision provides a professional basis for more modern planning of traffic calming measures and contributes to improved road safety, better intersection visibility, and a higher-quality traffic environment.

Keywords: traffic calming, unsignalized at-grade intersections, technical specification, road safety

1. INTRODUCTION

Unsignalized at-grade intersections represent an important element of the road network, where the crossing of traffic flows, various traffic manoeuvres, and conflict points result in increased road safety risks (Shi et al., 2025). Particularly important are the interactions between motorized and vulnerable road users, as the behaviour and safety of pedestrians and cyclists at unsignalized intersections are influenced by various factors related to road users, vehicle speeds, and the characteristics of the traffic environment (Chou et al., 2025; Nassereddine, H. (2025).

An important approach to improving road safety in urban areas is traffic calming. Traffic calming measures include various infrastructure solutions, among which vertical and horizontal measures play an important role, primarily aimed at reducing motor vehicle speeds and improving road safety (Majer et al., 2024). Modern traffic calming, however, includes a broader

* Corresponding author. Tel.: +386 69 756 545; e-mail address: ivana.prelovac@um.si (I. Prelovac).

range of physical and geometric, regulatory, perceptual, and technological measures. Recent systematic reviews indicate that physical and geometric measures provide the most consistent effects on speed reduction, while comprehensively planned traffic calming can also contribute to reducing traffic risks, improving conditions for active mobility, and enhancing the quality of urban spaces (Magkafas et al., 2025; Sadeqi Bajestani & Pirdavani, 2026).

In Slovenia, devices and measures for traffic calming at unsignalized at-grade intersections are addressed by the technical specification TSC 02.203:2009. Seventeen years have passed since its publication, during which design approaches and infrastructure solutions have developed significantly. Modern planning is increasingly focused on a comprehensive consideration of road safety, vulnerable road users, and the quality of the traffic environment. A previous review of 65 Slovenian and international sources showed that some modern measures are not included in the existing specification or are addressed in less detail than in more recent international guidelines.

The aim of this paper is to present a proposal for a revised Slovenian technical specification for traffic calming devices and measures at unsignalized at-grade intersections. The proposal is based on an analysis of the existing TSC 02.203:2009 and a review of Slovenian and international professional literature, technical guidelines, and examples of good practice. Particular emphasis is placed on supplementing and upgrading existing solutions and introducing new measures to support more modern and road-safety-oriented design of unsignalized at-grade intersections.

2. EXISTING TECHNICAL SPECIFICATION

2.1 Purpose and Scope of Application

TSC 02.203:2009 defines the requirements for the traffic engineering design of traffic calming devices and measures at unsignalized at-grade intersections on public and uncategorized roads intended for public road traffic. The specification does not address traffic calming at roundabouts or the technical design and dimensioning of mini-roundabouts.

The specified devices and measures are intended for use at intersections within built-up areas where road lighting is provided for the carriageway and roadside areas, while the intersection approaches may form part of the national or municipal road network. Within these conditions, the design of appropriate solutions takes into account basic criteria related to road function, speed, and traffic conditions, as well as additional criteria covering spatial, traffic, environmental, and other characteristics of the location under consideration.

2.2 Structure and Existing Measures

The existing technical specification is divided into eight main chapters. The introductory chapters define the subject of the specification, the terms used, and its purpose and scope of application. These are followed by basic and additional design criteria and the procedure for selecting an appropriate measure. The central part of the document is Chapter 7, which provides a more detailed description of individual traffic calming devices and measures, while the final chapter contains a legend of the graphical symbols used.

When selecting an appropriate solution, the characteristics of the location under consideration are taken into account, including the available width of the traffic area, the presence of an important cycling connection, and whether the traffic arrangement is one-way or two-way. The range of measures includes system-level and regulatory measures, warning devices, and infrastructure solutions such as raised intersections, road-axis shifts, reductions in intersection

area, central traffic islands, mini-roundabouts, and divided intersections. Individual solutions are supplemented by conditions of application, basic design characteristics, and graphical illustrations.

2.3 Limitations of the Existing Technical Specification

Seventeen years have passed since the publication of TSC 02.203:2009, during which approaches to traffic calming design and the planning of unsignalized at-grade intersections have continued to evolve. The existing specification provides an important technical basis; however, in view of developments in design approaches, new infrastructure solutions, and modern road safety requirements, it is appropriate to update and expand its content. Therefore, potential improvements were identified through a comparative review of more recent international guidelines and examples of good practice.

3. REVIEW OF MODERN APPROACHES AND DESIGN GUIDELINES

3.1 Methodology of the Literature and Source Review

To identify modern approaches to traffic calming at unsignalized at-grade intersections, a review of Slovenian and international literature was conducted. The review included scientific and professional sources, technical guidelines, standards, design manuals, and other relevant materials in the field of traffic planning and traffic calming. The focus was primarily on more recent sources published after 2010.

As part of the broader review, guidelines, recommendations, and examples of good practice, particularly from the Netherlands, Germany, the Czech Republic, and the United States, were selected for a more detailed comparative analysis. The selection was based on the relevance of the individual sources to the topic under consideration and their applicability in identifying potential improvements to the Slovenian technical specification.

The selected solutions were compared with the content of TSC 02.203:2009 in terms of their design, scope of application, and design characteristics. The comparison focused on identifying modern approaches and opportunities to supplement and improve the existing solutions.

3.2 Review Results

The review of modern international guidelines showed that approaches to traffic calming at unsignalized at-grade intersections are increasingly focused on the comprehensive design of the traffic environment. In addition to reducing motor vehicle speeds, emphasis is placed on adapting intersection geometry, providing clearer guidance of traffic flows, and improving conditions for pedestrians and cyclists.

The solutions reviewed include various forms of intersection area reduction, carriageway narrowing and shifts, reduced turning radii, central traffic islands, raised surfaces, and measures for restricting specific traffic manoeuvres. A specific group of solutions includes the design of entrances to 30 km/h speed limit zones, where traffic signs are complemented by geometric, vertical, or visual elements. The review also identified a greater variety of warning measures and solutions for the safer guidance of pedestrians and cyclists.

The comparison with the existing Slovenian specification showed that some of these approaches are already included in TSC 02.203:2009; however, more recent international guidelines include a broader range of measures and address individual solutions in greater detail. The main opportunities for improving the existing specification therefore relate to expanding the

range of geometric and warning measures, providing more detailed guidance on the design of entrances to speed-limited areas, and including additional solutions for the safer guidance of pedestrians and cyclists.

4. PROPOSAL FOR A REVISED TECHNICAL SPECIFICATION

4.1 Basis for the Revision

The main principle in developing the revised technical specification was to retain appropriate existing solutions while supplementing and improving them based on the identified needs. The revision focuses on expanding the range of measures, providing a more detailed definition of their application and design characteristics, and ensuring a clearer and more structured presentation of individual solutions.

4.2 Proposed Changes and Additions to the Technical Specification

Based on the findings of the comparative review, the key changes and additions to the existing technical specification were identified. The proposed revision includes both the improvement of existing measures and the introduction of new solutions, as well as a more detailed classification of individual groups of measures. The main changes to the content are summarized in Table 1.

Table 1. Comparison of the Existing and Revised Technical Specifications

Area	TSC 02.203:2009	Proposed Revision
Document structure	8 main chapters	12 main chapters and 2 appendices
Warning devices	Basic forms of warning measures	Expanded range of warning devices and optical speed bar configurations
Reduction of intersection area	Basic solutions for reducing the intersection area	More detailed classification and additional solutions
Restriction of traffic manoeuvres	Individual geometric solutions	A separate group of measures with additional solutions
Speed-limited areas	Limited coverage	Several approaches to designing entrances to 30 km/h zones
Cycling traffic	Considered mainly when selecting an appropriate measure	Additional infrastructure solutions for guiding bicycle traffic

The comparison shows that the revision is not limited to the introduction of individual measures, but also includes an expansion of the scope and a more detailed classification of the proposed solutions. In particular, the range of measures for restricting traffic manoeuvres and the number of solutions for designing entrances to speed-limited areas have been expanded. Additional design solutions for the safer guidance of bicycle traffic have also been included. The following sections present selected solutions illustrating different approaches to geometric redesign of intersections, regulation of traffic manoeuvres, and improvement of conditions for different road users.

4.3 Selected Solutions

The proposed revised technical specification includes several new and improved solutions for the design of unsignalized at-grade intersections. Some of the measures are presented below.

4.3.1 Set-Back Sidewalks

Set-back sidewalks (Figure 1) represent a new solution intended primarily for urban intersections with a high number of pedestrian crossings and for roads with parking, bicycle lanes, or multiple traffic lanes. The design is based on setting the sidewalk back from the edge of the carriageway and appropriately shaping the intersection corners, thereby reducing the crossing distance and time and improving the visibility of road users and sight conditions at the intersection. The geometry is adapted to the characteristics of the location and the selected design vehicle. Before permanent implementation, the effectiveness of the measure can be assessed through a trial sidewalk extension marked with road markings and protected by temporary (Ministerstvo dopravy, 2024; Ministrstvo za regionalni razvoj in javna dela, Ministrstvo za notranje zadeve, 2024).

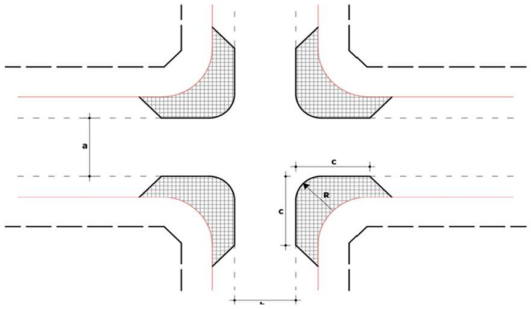


Figure 1. Set-Back Sidewalks

4.3.2 Reduction of Turning Radii Combined with a Raised Intersection

The reduction of turning radii combined with a raised intersection represents one of the new solutions included in the proposed revised technical specification. The design is based on the geometric modification of the intersection corners and the elevation of the intersection surface. The turning radii are determined according to the selected type of design vehicle (Ministrstvo za regionalni razvoj in javna dela, Ministrstvo za notranje zadeve, 2024; NACTO, 2016; City of Ottawa, 2019). Such an arrangement combines the geometric redesign of the intersection with a vertical traffic calming measure, with the basic design of the solution shown in Figure 2.

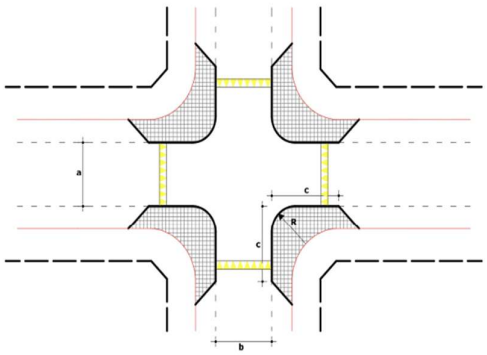


Figure 2. Reduction of Turning Radii Combined with a Raised Intersection

4.3.3 Staggered Intersection for Different Types of Road Users

The staggered intersection for different types of road users (Figure 3) is intended for roads with a collector or access function. The design is based on shifting the alignment of road (2), thereby interrupting its direct path through the intersection and changing the way vehicles enter or turn between roads (1) and (2), as shown in Figure 3. The intersection must be clearly recognizable, particularly through appropriate traffic signs and road lighting.

The solution can be combined with speed reduction measures, cycling facilities, gateway treatments, and additional elements to improve visibility and recognition. Its advantages include increasing drivers' attention when approaching the intersection, reducing vehicle speeds on road (2), and facilitating certain turning manoeuvres. Potential limitations should also be considered in the design, particularly reduced traffic capacity, more difficult manoeuvring for heavy vehicles, and the possibility of congestion under higher traffic volumes (CROW, 1998).

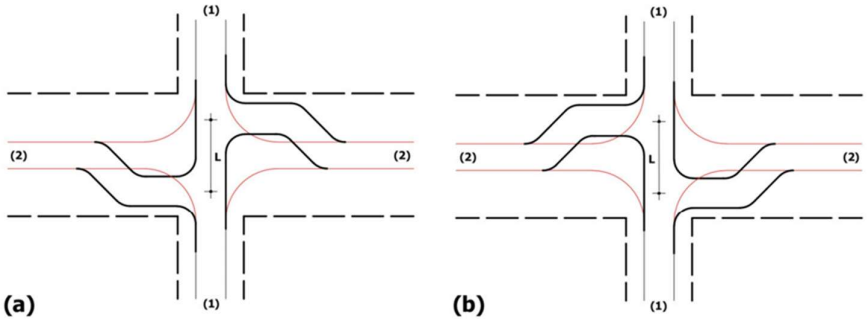


Figure 3. Staggered Intersection for Different Types of Road Users

4.3.4 One-Way Traffic at a Four-Leg Intersection

One-way traffic at a four-leg intersection represents a solution in which a one-way traffic arrangement is introduced on part of the carriageway. The suitability of the measure is assessed through an analysis of traffic flows, through traffic, deliveries, access to buildings, emergency access routes, and pedestrian and cycling connections. The impact of traffic diversion on adjacent

roads should also be assessed. The proposed revised technical specification includes several possible arrangements: a mixed-traffic carriageway with partial one-way traffic without parking, with parallel parking on the carriageway, with parallel parking in parking bays on both sides, and with parallel parking in parking bays on one side. Two of the proposed arrangements are shown in Figure 4.

The measure is intended for very sharp turns on corner streets where there is no interchange of traffic flows, as well as for reducing the volume of through traffic continuing straight ahead. Where possible, a separate cycling connection in the opposite direction to motor vehicle traffic may also be provided. The advantages of the measure include discouraging through traffic from passing through the area, creating clearer traffic situations, and providing the possibility of gaining additional space for parking or public space (City of Ottawa, 2019).

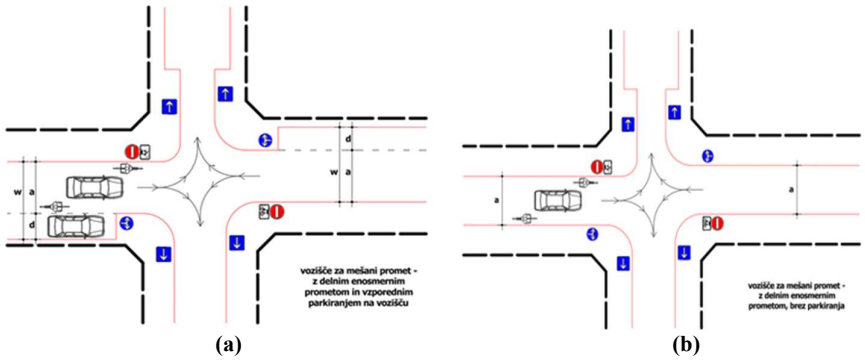


Figure 4. (a) One-way traffic at a four-leg intersection – mixed-traffic carriageway with partial one-way traffic and parallel parking on the carriageway; (b) one-way traffic at a four-leg intersection – mixed-traffic carriageway with partial one-way traffic, without parking

4.3.5 Diagonal Closure with Bicycle Crossings

A diagonal closure with bicycle crossings is a solution whose suitability is determined based on an analysis of the traffic composition, whereby the measure is not suitable for main roads. The closure must be clearly and unambiguously visible in advance from all intersection approaches, while permitted and prohibited directions of travel must be clearly indicated by the geometry of the measure and traffic signs. Appropriate elements should be used to prevent vehicles from bypassing the closure via sidewalks, cycling facilities, or other areas. Separate crossings for pedestrians and cyclists may be provided through the closure. Where access for emergency or other authorized vehicles is required, a controlled removable, retractable, or traversable barrier may be installed.

The measure physically prevents motor vehicle through traffic from passing through the intersection and reduces the volume of motor traffic on filtered streets. At the same time, it maintains network permeability for pedestrians and cyclists and reduces the number of permitted conflicting manoeuvres. It also allows part of the intersection to be converted into public space, green space, or another non-vehicular area (CROW, 1998). Two possible configurations of the measure are shown in Figure 5.

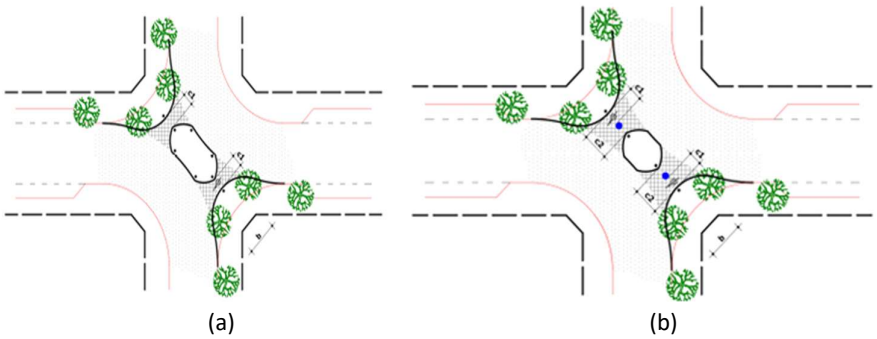


Figure 5. (a) Diagonal closure with bicycle crossings; (b) diagonal closure with bicycle crossings and access for emergency vehicles

4.3.6 Closure of an Access Road with a Pedestrian and Bicycle Crossing

Closure of an access road with a pedestrian and bicycle crossing is a measure whose suitability is determined based on an analysis of the traffic composition. The design must ensure that the closure and the permitted ways of continuing the journey are clearly and promptly recognizable. Appropriate elements should be used to prevent motor vehicles from entering areas intended for pedestrians and cyclists. The bicycle connection should be provided in a different pavement colour from the traffic lanes for motor vehicles. Where access for emergency vehicles is provided, the bicycle connection may run along the centre of the carriageway using a flexible barrier, as shown in Figure 6

The measure physically prevents motor vehicle through traffic from passing through the access road while maintaining a direct connection for pedestrians and cyclists and allowing the creation of dead-end streets with moderate-speed traffic areas. The design should also consider the limited route choice for motor traffic, the possibility of increased speeds on alternative routes, and the impact on local service traffic (CROW, 1998).

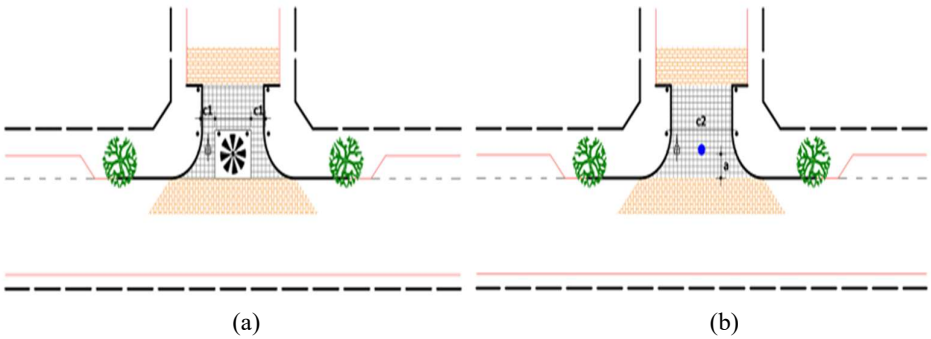


Figure 6. (a) Closure of an access road with a pedestrian and bicycle crossing; (b) closure of an access road with a pedestrian and bicycle crossing (access provided for emergency vehicles/deliveries)

4.3.7 Entrance to a 30 km/h Zone at a Four-Leg Intersection with the Priority Road Following a Curve

Entrance to a 30 km/h zone at a four-leg intersection with the priority road following a curve is intended for locations with lower traffic volumes and speeds, where there are no cycling facilities or bus and/or delivery traffic in the area under consideration. The design is based on the use of a bevelled or lowered kerb along the side of the carriageway, a continuous sidewalk with a uniform pavement colour and, where possible, the same type of paving material. The kerbs are designed without curved sections. To ensure that the arrangement is clearly recognizable, appropriate vertical elements, street lighting, and traffic signs for the 30 km/h speed limit zone should be provided. The alignment of the priority road through the curve, together with the two non-priority approaches, must be clearly indicated by the geometric design and appropriate traffic signs (CROW, 1998). An example of the arrangement is shown in Figure 7.

The advantages of the measure include a very low entry speed into the 30 km/h speed limit zone, a clear transition into the zone, and the possibility of influencing route choice by discouraging through traffic. The design should take into account that bevelled kerbs may present an obstacle to cyclists. Due to the geometrically direct continuation onto the non-priority approaches, there may also be ambiguity regarding priority between vehicles following the priority road through the curve and vehicles continuing straight ahead onto the non-priority approaches (CROW, 1998).

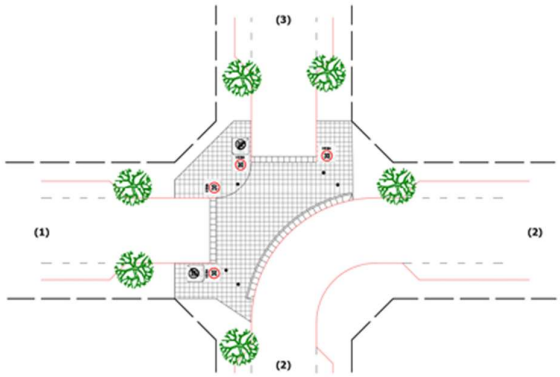


Figure 7. Entrance to a 30 km/h Zone at a Four-Leg Intersection with the Priority Road Following a Curve

4.3.8 Entrance to a 30 km/h Zone via a Continuous Sidewalk

Entrance to a 30 km/h zone via a continuous sidewalk is intended for locations with lower traffic volumes, where there are no cycling facilities on the side road and no bus and/or delivery traffic on the main road. The design is based on a continuous sidewalk with a uniform pavement colour and, where possible, the same type of paving material. The design of the side road must clearly indicate the 30 km/h speed limit zone and must not create the false impression that pedestrians have the rights associated with a traffic-calmed area across the entire width of the road. Traffic signs indicating the 30 km/h speed limit zone are also provided to ensure that the zone is clearly marked (CROW, 1998). An example of the arrangement is shown in Figure 8.

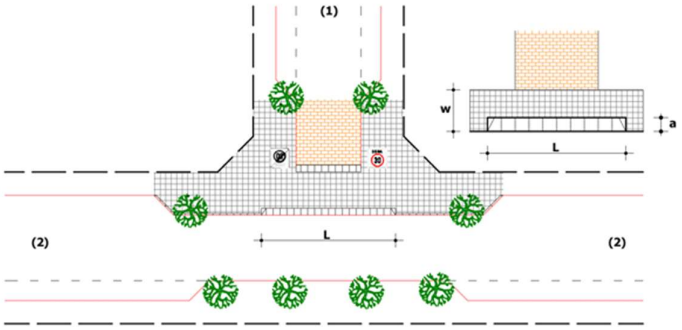


Figure 8. Entrance to a 30 km/h Zone via a Continuous Sidewalk

5. CONCLUSION

This paper addressed the need to revise the technical specification TSC 02.203:2009 for traffic calming devices and measures at unsignalized at-grade intersections. Based on an analysis of the existing specification and a review of Slovenian and international literature, technical guidelines, and examples of good practice, modern approaches and opportunities for its improvement were identified. On this basis, a proposal for a revised technical specification was developed, incorporating improvements to existing solutions as well as new design solutions.

The main findings of the review indicate that some modern approaches are already included in the existing TSC; however, more recent international guidelines cover a broader range of measures and address individual solutions in greater detail. Opportunities for improvement relate primarily to the geometric design of intersections, restriction of traffic manoeuvres, design of entrances to speed-limited areas, and improvement of conditions for pedestrians and cyclists.

Compared with the existing TSC 02.203:2009, the proposed revision expands the scope from unsignalized at-grade intersections to include access roads and increases the document from eight to twelve main chapters and two appendices. The range of warning devices and optical speed bar configurations has been expanded, solutions for reducing intersection areas and restricting traffic manoeuvres have been classified in greater detail, additional approaches to designing entrances to 30 km/h speed limit zones have been included, and new infrastructure solutions for guiding bicycle traffic have been introduced. The revision therefore involves not only the addition of new measures but also a more detailed and transparent presentation of their application and design characteristics.

The proposed revision provides a technical basis for further updating the technical specification and for a more modern and comprehensive approach to designing traffic calming measures at unsignalized at-grade intersections.

6. REFERENCE

[1] Chou, K. Y., Paulsen, M., Møller, M., & Jensen, A. F. (2025). Cyclists' mobility and subjective safety in shared urban spaces-a simulator study. Transportation Research Part F: Traffic Psychology and Behaviour, 103321.

[2] CROW (1998). Recommendations for traffic provisiors in built-up areas ASVV. The Netherlands, CROW 1010.

[3] Magkafas, F., Fountas, G., Anastasopoulos, P. C., & Basbas, S. (2025). Beyond speed reduction: A systematic literature review of traffic-calming effects on public health, travel behaviour, and urban liveability. Infrastructures, 10(6), 147.

[4] Majer, S., Sołowczuk, A., Kurnatowski, M. (2024). Design and Construction Aspects of Concrete Block Paved Vertical Traffic-Calming Devices Located in Home Zone Areas. Sustainability, 16 (7).
[5] Ministerstvo dopravy (2024). TP 132 Zásady zklidňování dopravy na pozemních komunikacích v obcích. Plzeň, EDIP Komplexní služby v oboru dopravního inženýrství.
[6] Ministrstvo za regionalni razvoj in javna dela, Ministrstvo za notranje zadeve (2024). Uredba št. […] o pogojih za gradnjo ali namestitev umetnih ovir in drugih naprav za omejevanje hitrosti na vozišču ter o zahtevah v zvezi s tem. Sofia, Bulgaria, 31.
[7] NACTO (2016). Global Street Design Guide. New York, National Association of City Transportation Officials, 426.
[8] Nassereddine, H. (2025). Modeling vehicle-pedestrian interactions at unsignalized intersections. Journal of Transportation Safety & Security, 17 (6), 664–682.
[9] Ottawa, City of Ottawa, Transportation Services Department, Active Transportation Management Branch (2019). Traffic Calming Design Guidelines. Ottawa, 122.
[10] Sadeqi Bajestani, M., & Pirdavani, A. (2026). Traffic Calming Measures in Urban Environment: A Systematic Review. Infrastructures, 11(5), 148.
[11] Shi, H., Chen, F., Du, H., Zhang, T., & Li, C. (2025). Evaluating the impact of self-luminous road markings on driver behavior at unsignalized intersections: A simulator study. Accident Analysis & Prevention, 214, 107967.