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ROAD SAFETY AND SUSTAINABLE URBAN MOBILITY

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Abstract: Road safety is regarded as a subsystem of the transport system, although in practice it is also frequently considered a characteristic of the overall condition and performance of the transport system. Road safety is monitored and guided through documents adopted at the international level, at national level, and at the level of local communities. The most important strategic documents at national and local levels are road safety strategies. Sustainable urban mobility aims to ensure that the transport needs of users, namely residents and visitors in urban areas, are met to the greatest possible extent, while also enabling less mobile road users to travel. At the same time, transport should be organised in a sustainable manner in terms of energy consumption, land use, environmental criteria, and the level of safety provided to road users. The most important documents concerning sustainable urban mobility at the urban-area level are Sustainable Urban Mobility Plans. This paper analyses the relationship between road safety and sustainable urban mobility from the perspective of the influence of these subsystems within the transport system, the content of each of the areas under consideration, and the links between the documents relating to these two fields, namely road safety strategies and sustainable urban mobility plans. Particular attention is given to areas addressed both within road safety and sustainable urban mobility, including transport-related environmental impacts, the treatment of vulnerable road users, the role of public passenger transport, parking capacity management, traffic management, and road safety management.

Keywords: road safety, sustainable urban mobility, road safety strategy, sustainable urban mobility plan.

1. INTRODUCTION

The fields of sustainable urban development and road safety are shaped by strategic documents adopted at the level of the United Nations, the European Union, and the Republic of Serbia. In 2015, the United Nations adopted the Sustainable Development Goals to be achieved by 2030. Goals 3 and 11 are directly related to road safety and sustainable cities. Goal 3 included the target of halving the number of road traffic deaths, while Goal 11 calls for access to safe, affordable, accessible and sustainable transport systems for all, with particular attention to vulnerable groups. In the field of road safety, the United Nations adopted the *Global Plan for the Decade of Action for Road Safety 2021–2030*, supporting the implementation of Resolution 74/299 *Improving Global Road Safety*. Its objective is to reduce road traffic deaths and injuries by at least 50% during the decade and to promote the Safe System approach. These documents

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provide a basis for national and regional road safety strategies, including those of the European Union and the Republic of Serbia.

Sustainable urban mobility has become increasingly important in EU policy, particularly because more than 70% of EU citizens live in urban areas and transport remains a major source of greenhouse gas emissions. The *EU Urban Mobility Framework* therefore promotes urban transport systems that are safe, accessible, inclusive, affordable, smart, resilient and low- or zero-emission. A major step in this process was the Green Paper *Towards a New Culture for Urban Mobility* (European Commission, 2007), which identified congestion and pollution as key urban transport challenges and promoted walking, cycling, public transport and reduced dependence on private cars.

The European Commission further developed this approach through the 2013 *Urban Mobility Package* and the first *Guidelines for Developing and Implementing a Sustainable Urban Mobility Plan*. Subsequent EU policy increasingly strengthened the role of Sustainable Urban Mobility Plans (SUMPs), particularly through Commission Recommendation (EU) 2023/550, which requires Member States to establish national support programmes for sustainable urban mobility planning. The EU approach also promotes a shift from traffic-flow-oriented planning towards the sustainable movement of people and goods, with greater emphasis on public transport, active mobility, urban logistics, multimodal hubs and digital solutions. This approach is also linked to the Trans-European Transport Network (TEN-T), since urban mobility plays an important role in the "first and last mile" movement of passengers and freight. The revised TEN-T Regulation requires Member States to establish national support structures for SUMPs, while the latest guidance is provided in the third edition of the *Guidelines for Developing and Implementing a Sustainable Urban Mobility Plan* (Rupprecht Consult, 2026).

Overall, this policy framework supports the development of urban areas that are more people-oriented, with safer conditions for vulnerable road users, reduced dependence on motor vehicles, stronger public transport, cleaner air, and greater social and environmental sustainability.

2. CONCEPTS OF ROAD SAFETY AND SUSTAINABLE URBAN MOBILITY

The concept and subject matter of road safety as a scientific field were among the first to be comprehensively defined by Prof. M. Inić (1991), who described it as one of the scientific disciplines that, through the application of scientific methodology, monitors, studies and explains the manifestations, causes, conditions and other factors leading to phenomena that endanger people and property in traffic, particularly road traffic accidents, as well as strategies for preventing road traffic accidents and other phenomena that threaten societal values within the transport system. In doing so, road safety draws not only on its own research findings but also on the results of other scientific disciplines. According to Prof. M. Inić, the field of road safety can be viewed through three segments of action and structure: phenomenology, aetiology and prevention. All three are directed towards reducing the harmful consequences of traffic, primarily by reducing the number and severity of road traffic accidents and by preventing their occurrence. Today, the subject matter of road safety may be considered in both a broader and a narrower sense (Lipovac et al., 2019). In the broader sense, road safety encompasses all negative effects and consequences of traffic, whereas in the narrower sense it is associated exclusively with road traffic accidents and their consequences.

The conventional analytical approach within the road safety system has generally involved assessing the effects of active and passive safety measures on each of the four basic subsystems: Human – Vehicle – Road – Environment. The approach adopted in the preparation of road safety strategies is based on consideration of the following areas: road safety management, safe roads, safe vehicles, safe road users and post-crash response.

Key strategies for improving safety include improvements in traffic and road design, such as roads designed to minimise conflicts between traffic flows, sufficiently wide pavements, pedestrian crossings with clearly visible markings and signs, and physical barriers separating areas used by vehicles from those intended for pedestrians. Such measures can reduce the risk of road traffic accidents while also encouraging urban populations to use more sustainable modes of transport. Depending on the purpose for which the term is used, road safety may also be understood in a considerably narrower sense, namely as a characteristic of the transport system describing the extent to which that system is safe for all road users. This includes groups that receive particular attention in road safety strategies and sustainable urban mobility plans, such as pedestrians, cyclists, motorcyclists, public transport users, older people, children, users of micromobility vehicles and similar groups.

Sustainable urban mobility can be defined as a condition, strategy and concept for meeting the mobility needs of urban residents through sustainable transport technologies, while balancing mobility with important human and environmental values, both now and in the future (Tica et al., 2021). It also supports sustainable urban development and quality of life and is closely related to the structure and efficiency of the transport system. Its main objective is to reduce dependence on private cars and promote alternative modes such as walking, cycling and public transport, thereby reducing harmful emissions, air pollution and traffic congestion.

Figure 1 provides a schematic representation of the objectives associated with the main elements of sustainable urban mobility.

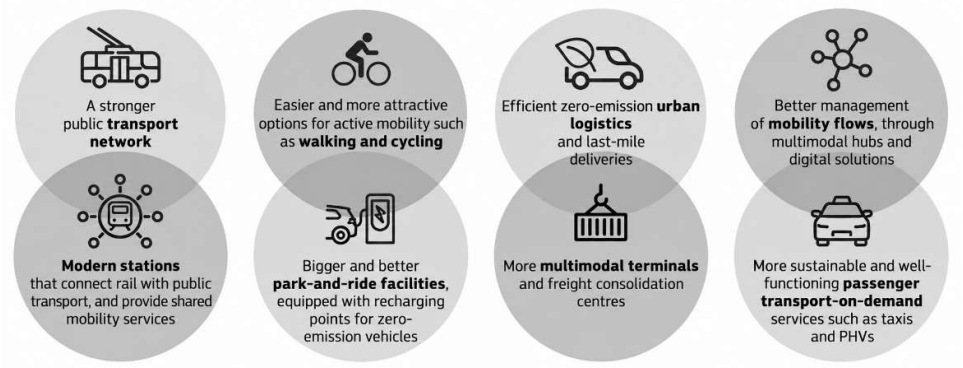


Fig. 1. Relationship between the elements of sustainable urban mobility
Source: European Commission. Sustainable urban mobility. https://transport.ec.europa.eu/transport-themes/urban-transport/sustainable-urban-mobility_en

Integrating sustainable mobility principles into urban planning can provide long-term, safe and environmentally responsible transport solutions. Measures such as cycle lanes, pedestrian zones, improved public transport, car-sharing and ride-sharing can reduce car dependence and improve quality of life. Sustainable urban mobility also includes micromobility, which can contribute to reducing road traffic accidents, congestion, pollution, noise and parking pressures (Ranković & Ranković Plazinić, 2024). Digital traffic management solutions, including sensors, applications and data analytics, further support real-time monitoring and traffic-flow optimisation.

A key feature of sustainable urban mobility is integration within Sustainable Urban Mobility Plans, covering all transport modes, transport network planning and cross-sectoral urban development strategies. Participation of relevant stakeholders is also essential. Integrated travel

applications can improve access to public transport and reduce reliance on private cars, while smart technologies such as intelligent traffic signals, cameras and speed-monitoring sensors can improve road safety and incident response (Tica et al., 2021).

3. RELATIONSHIP BETWEEN SUSTAINABLE URBAN MOBILITY AND ROAD SAFETY

The relationship with road safety is embedded in the very definition of sustainable urban mobility, since sustainable urban mobility implies the integrated planning of the transport system in which mobility needs are met while simultaneously improving accessibility, quality of life, environmental protection and the safety of all road users. In this context, the principal planning document, the Sustainable Urban Mobility Plan, does not consider individual modes of transport in isolation, but integrates public transport, walking, cycling, micromobility, individual car transport, parking, urban logistics and traffic management. Contemporary SUMP guidelines place particular emphasis on the integration of all modes of transport while giving priority to sustainable modes, improving public transport safety, developing safe pedestrian and cycling networks, protecting vulnerable road users, managing parking, and reducing congestion (Rupprecht Consult, 2026).

Road safety represents an integral component of sustainable mobility, since a transport system cannot be regarded as sustainable if meeting mobility needs is associated with a high risk of road traffic accidents and casualties. Anastasiadou and Kehagia (2025) explicitly identify road safety as a structural element of sustainable urban mobility, emphasising that a safer urban environment also encourages walking, cycling and other sustainable modes of travel. Within the SUMP framework, road safety should therefore not be regarded merely as a separate objective, but rather as a horizontal requirement that should be incorporated into infrastructure planning, speed management, the organisation of public transport, parking management and the design of public space (Anastasiadou & Kehagia, 2025; Rupprecht Consult, 2026).

A further important aspect of this relationship is the effect of changes in modal split on road safety. Measures that encourage a shift from private cars to walking, cycling and public transport can reduce traffic volumes, congestion and environmental impacts, but they may also increase the exposure of vulnerable road users if appropriate safety measures are not implemented simultaneously. For this reason, sustainable mobility policies should be accompanied by safe infrastructure, speed management and measures aimed at reducing conflicts between motorised and non-motorised road users (Schepers & Heinen, 2013; Schepers et al., 2014).

According to the authors cited in Table 1, the relationship between the sustainable urban mobility system, considered through the SUMP framework, and road safety can be presented schematically, as shown in Figure 2. The essence of this representation is that the road safety system integrates all SUMP elements into a unified framework, thereby contributing to the achievement of the established objectives. A particularly important link between sustainable mobility and road safety arises in the context of changes in modal split. Shifting a proportion of short trips from private cars to bicycles contributes to reducing car dependence, parking problems, congestion, and the adverse environmental impacts of transport. However, an increased share of cycling must be accompanied by simultaneous improvements in cyclist safety.

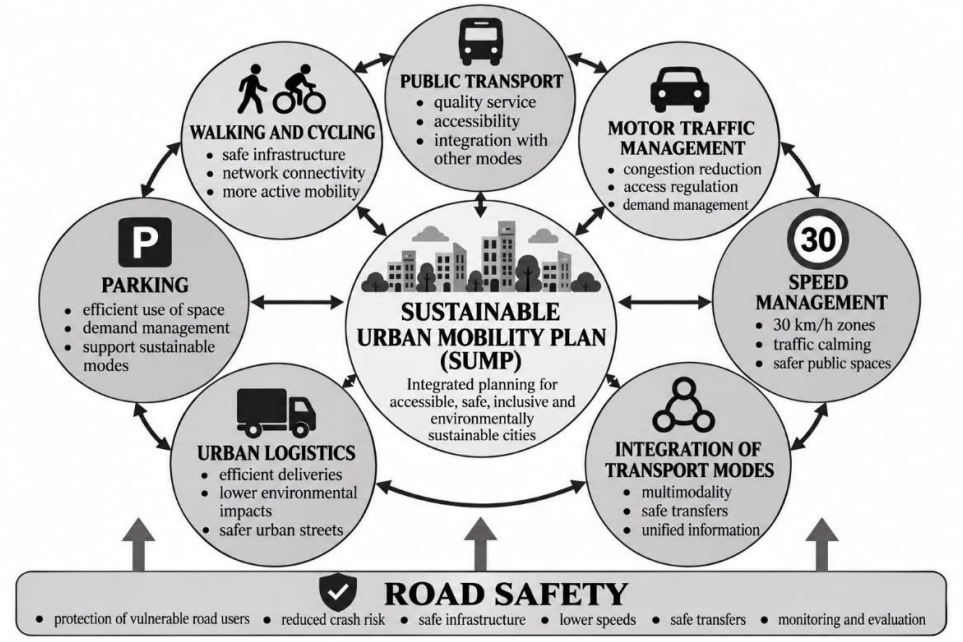


Fig. 2. Integration of road safety into the sustainable urban mobility system (SUMP)
Source: Authors' synthesis based on Rupprecht Consult (2026), Schepers et al. (2014), Munkácsy et al. (2024), Anastasiadou and Kehagia (2025), Jurak et al. (2025) and Kapousizis et al. (2021).

Schepers and Heinen (2013) show that replacing short car journeys with cycling does not necessarily lead automatically to improvements in all road safety indicators, as the number of seriously injured cyclists may increase in the absence of additional measures. For this reason, changes in modal split should be implemented together with the development of safe infrastructure and measures aimed at reducing risk (Schepers & Heinen, 2013; Schepers et al., 2014).

Safely designed infrastructure represents one of the key prerequisites for increasing the share of active modes of mobility. Research indicates that intersection characteristics, carriageway width, parked vehicles, the organisation of cycling facilities, and the interaction between bicycle and motor traffic are associated with the risk of cyclist injuries (Kapousizis et al., 2021). In addition to objective risk, perceived safety is also highly important, since a sense of insecurity may discourage people from cycling and thereby limit the effectiveness of sustainable mobility policies (Schepers et al., 2014; Ye et al., 2024).

Road safety is closely linked to sustainable urban mobility, and this relationship stems from the fact that, as the number of vehicles increases and urban areas continue to develop and expand, the risk of road traffic accidents also increases (Ranković & Ranković Plazinić, 2024). The relationship between sustainable urban mobility and road safety is evident and is of key importance for the future development of urban areas. Sustainable mobility contributes to reducing adverse environmental impacts, while smart cities use technology to improve efficiency and quality of life. Road safety, as a central aspect of these concepts, ensures that roads and urban transport environments are safe for all road users, which is also a direct objective of sustainable urban mobility. Table 1 presents the relationship between SUMP elements and road safety on the basis of the analysed sources.

Table 1. Relationship between SUMP elements and road safety

Sustainable urban mobility element	Role within the SUMP	Relationship with road safety	Source
Walking	Increasing the share of active mobility and improving the quality of public space	Requires safe pedestrian areas and crossings, as well as the reduction of conflicts with motor traffic	Anastasiadou & Kehagia, 2025; Rupprecht Consult, 2026
Cycling	Providing an alternative to short car journeys	Increasing levels of cycling should be accompanied by risk reduction and the development of high-quality infrastructure	Schepers & Heinen, 2013; Schepers et al., 2014; Kapousizis et al., 2021
Public transport	A key component of a sustainable mobility system	The safety and accessibility of stations, vehicles and pedestrian access routes affect the attractiveness and acceptability of public transport	Munkácsy et al., 2024; Rupprecht Consult, 2026
Speed management	Reducing the dominance of motor traffic and creating a higher-quality urban environment	Lower speeds reduce both the likelihood and severity of road traffic accidents, particularly for vulnerable road users	Jurak et al., 2025
Parking	Managing car use and the allocation of public space	Parked vehicles can create conflicts, reduce visibility and increase risks for cyclists	Kapousizis et al., 2021; Rupprecht Consult, 2026
Motor traffic management	Reducing congestion and promoting more efficient use of infrastructure	Fewer conflicts, lower speeds and reduced exposure contribute to a safer urban transport system	Schepers et al., 2014; Rupprecht Consult, 2026
Integration of transport modes	Connecting walking, cycling, public transport and other forms of mobility	Safe transfers between modes and well-designed public space are prerequisites for effective multimodality	Munkácsy et al., 2024; Rupprecht Consult, 2026
Monitoring and management	Monitoring the achievement of SUMP objectives	Monitoring road traffic accidents, risks and mobility indicators enables measures to be adjusted accordingly	Anastasiadou & Kehagia, 2025; Rupprecht Consult, 2026

Source: Authors' analysis based on Schepers and Heinen (2013), Schepers et al. (2014), Kapousizis et al. (2021), Munkácsy et al. (2024), Anastasiadou and Kehagia (2025), Jurak et al. (2025) and Rupprecht Consult (2026).

One measure with particularly strong combined effects on both sustainability and road safety is the introduction of 30 km/h speed limit zones. Lower speeds contribute to reducing the frequency and, especially, the severity of road traffic accidents, improve conditions for pedestrians and cyclists, and support the development of a more people-oriented urban environment. Jurak et al. (2025) therefore consider 30 km/h zones as part of a broader urban mobility management strategy and refer to their application within the SUMP of the City of Križevci. In this way, the integrated management of speed, public transport, active mobility, parking, and infrastructure makes it possible to pursue sustainable mobility and road safety objectives simultaneously, rather than as separate policy areas (Jurak et al., 2025; Munkácsy et al., 2024).

4. COMMON AREAS OF INFLUENCE OF ROAD SAFETY AND SUSTAINABLE URBAN MOBILITY

Important common areas influencing both road safety and sustainable urban mobility include transport ecology, which also considers the consequences of road traffic accidents among the harmful effects of transport; the treatment of vulnerable road users, such as pedestrians, cyclists, motorcyclists, micromobility users, older people and persons with special needs; the role of public passenger transport in reducing car use; and traffic and road safety management aimed at mitigating deficiencies in inherited infrastructure and unsafe road-user behaviour. From the perspective of sustainable urban mobility, priority should be given to modes of transport with low or no environmental impact, such as walking, cycling and electric vehicles. From the road safety perspective, these modes require appropriate infrastructure that improves both safety and accessibility.

4.1. Transport ecology

One of the main principles of sustainable urban mobility is to reduce the environmental impact of transport in urban areas. Urban transport ecology includes transport infrastructure, land use, energy, the environment and the population, and is an important component of environmentally sustainable and liveable cities. Air pollution and traffic congestion are among the main challenges of environmentally sustainable urban development. Another important characteristic is urban resilience, understood as the ability of a city to absorb external disturbances while maintaining its basic structure and essential functions (Resilience Alliance, 2007). Ecological resilience in urban transport has therefore become an important element of sustainable urban development.

Transport ecology is influenced by factors such as industrial pollution, motor vehicle emissions, household pollution, public transport, infrastructure quality, precipitation, population density and urban greenery. Urban governance capacity has been identified as one of the strongest determinants of ecological resilience, while technological innovation appears to have a comparatively weaker influence. Policies aimed at reducing energy consumption and transport-related emissions also support the transition towards a low-carbon economy.

Li and Zhao (2021) found that, in Guangzhou, low-carbon transport policies contributed 4.42% to improvements in the ecological condition of the urban transport system. Such policies can support public transport, increase the share of environmentally sustainable modes, reduce congestion, and decrease travel time and vehicle kilometres travelled.

In this context, transport ecology provides an important link between sustainable urban mobility, environmental protection and the long-term quality of urban life.

4.2. Treatment of vulnerable road users

Increasing the use of environmentally sustainable modes of travel, such as walking, cycling and micromobility, requires the development of appropriate infrastructure. Vulnerable road users, including pedestrians, cyclists and users of electric scooters, therefore occupy an important place within the concept of sustainable urban mobility, and infrastructure investment should be directed towards improving their safety and accessibility.

Jovanović and Bačkalić (2026) emphasise perceived road safety as an important factor influencing road-user behaviour and the use of alternative modes of travel. Their survey indicates that around 60% of respondents believe that drivers often fail to give way to pedestrians at crossings, more than 50% consider speeding common in pedestrian areas, and over 80% believe

that drivers often overtake cyclists or micromobility users too closely. More than 80% also consider cycling and micromobility infrastructure in the Autonomous Province of Vojvodina unsafe or insufficiently developed. Such conditions can discourage walking, cycling and micromobility.

Pedestrian safety is particularly affected at crossings and intersections, where conflicts with motor vehicles are more frequent. According to Haque et al. (2025), pedestrian accidents at intersections account for between 8% and 35% of all pedestrian accidents. Inadequate pedestrian infrastructure, poorly visible crossings and insufficient lighting additionally increase risk (Rilak et al., 2026).

In the City of Bor, 39% of road traffic accidents involving fatalities between 2020 and 2024 included pedestrian fatalities, while 26% of injury accidents involved injured pedestrians (Ranković et al., 2020). Improving safety therefore requires better infrastructure, safer behaviour by motorised users, and education of vulnerable road users themselves, including the promotion of helmets, reflective clothing and attentive road crossing.

4.3. Role of urban public passenger transport

Within Measure 2.4 “Cleaner urban transport and commuting” of the EU White Paper, the European Commission (2011) promotes public urban transport as a primary mode of travel in cities, together with alternative propulsion systems and travel modes aimed at reducing CO_2 emissions. Efficient public transport networks are essential for sustainable urban mobility. Smart-city technologies, connected vehicles and infrastructure, and autonomous systems can improve both transport efficiency and road safety. London provides a developed example, combining Underground, buses, Overground, DLR, tram and river services, supported by priority lanes, operational control centres and signal priority for public transport vehicles.

Copenhagen has also introduced journey-planning systems and the “CopenPay” concept, which rewards tourists for replacing car or taxi trips with cycling or public transport. Smart public transport systems also include electronic ticketing, GPS vehicle tracking and real-time information. One important challenge is travel time, particularly where vehicles are delayed by congestion or frequent stops. Bus Rapid Transit (BRT), with segregated lanes and level boarding platforms, can reduce these delays. Passenger confidence also depends on well-designed stops with lighting, surveillance, seating, wheelchair access, audio announcements and information displays, as well as acceptable walking distances to stops.

4.4. Traffic and road safety management

Urban transport systems are complex and dynamic structures whose operation is essential to the functioning of modern cities. Technological development enables these systems to adapt more effectively to changing mobility needs and supports more efficient and safer transport management. Adaptive traffic signal control represents an important element of sustainable urban mobility. By using cameras, sensors and machine-learning algorithms, signal timings can be adjusted to actual traffic demand, which is not possible with traditional fixed-time systems (Obradović et al., 2026). Even greater effects can be achieved through coordinated signal control across an urban network.

Ulvi et al. (2024) developed an urban mobility optimisation model based on factors such as time of day, spatial variations, weather, special events, road works, road traffic accidents, socio-economic conditions and traffic regulations. Using real-time data, the model enables more efficient and adaptive signal control, reducing congestion under both normal conditions and unexpected events such as accidents or vehicle breakdowns.

4.5. Parking capacity management

In addition to dynamic traffic management, sustainable urban mobility also requires effective parking management, particularly in urban areas and major activity centres. Rocco et al. (2023) propose an IoT-based smart parking architecture for public authorities and private operators. Searching for parking during peak periods increases congestion, fuel consumption, emissions and travel time. Examples from Treviso and Mantua indicate that smart parking systems can improve parking management and reduce traffic and pollution, although limitations remain where several drivers are directed towards the same available space. Parking is increasingly considered part of the wider Mobility as a Service (MaaS) concept, together with bike-sharing, car-sharing and micromobility. Mutambik (2025) notes that searching for parking increases travel time, fuel consumption and emissions, while fixed pricing and rigid allocation cannot respond adequately to fluctuating demand. A central trip-planning agent can dynamically allocate and redirect vehicles to available parking spaces based on distance, previous patterns and predicted availability. Parking policy is also important at transport terminals and interchange points, where sufficient parking and alternative travel options can reduce car use in central areas. Such locations should also provide appropriate infrastructure for pedestrians, cyclists and light electric vehicles. A particularly important approach is demand management in favour of sustainable transport modes.

Ranković et al. (2020) describe this as a scenario in which a broad set of measures is used to reduce the share of private cars and increase walking, cycling and public transport. This requires attractive alternatives to car travel, including alternative transport modes, alternative locations for activities, and opportunities to carry out activities from home.

5. CONCLUSION

The analysis of road safety and sustainable urban mobility shows that their key elements—walking and cycling, public transport, speed management, parking, traffic management, integration of transport modes, and monitoring—are closely interconnected. This relationship is also reflected in their principal strategic documents, namely the Road Safety Strategy and the Sustainable Urban Mobility Plan. The main conclusion is that road safety and sustainable urban mobility are mutually dependent subsystems of the transport system at national, urban and local levels, without either being hierarchically superior. Road safety is also a characteristic of the overall condition of the transport system and provides indicators for assessing sustainable urban mobility through the analysis of road traffic accidents and their consequences. Most countries, including the Republic of Serbia, regulate road safety through laws and strategic documents.

In sustainable urban mobility, the European Union has gradually moved since 2013 from recommendations towards more binding requirements and a clearer legal basis for Sustainable Urban Mobility Plans. In Serbia, however, there is still no specific legal basis requiring such plans. They are mainly developed at local level within the framework of the Sustainable Urban Development Strategy and through cooperation projects, support from EU Member States, and the involvement of domestic institutions and professional organisations.

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