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A Cognitive Review of Urban Traffic Calming Measures

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ABSTRACT. Urban roads have always facilitated traffic movement between different regions, serving as the main road systems for metropolitan transportation networks. In developing nations, vehicles with varying physical and dynamic attributes share the same road space, unlike in developed countries where cars and heavy vehicles dominate the entire traffic. Over-speeding has turned out to be a key contributor in majority of road fatalities, significantly influencing the severity of injuries in an accident. Traffic calming is effective particularly in areas where speeds are either excessive or unsuitable for the road's function and usage. Such measures include speed humps, speed tables, chicanes, speed bumps, rumble strips, and roundabouts to reduce vehicle speeds, lower accident rates, and create safer spaces where vulnerable road users such as children and the elderly are at higher risk. It not only improves traffic safety but also fosters a more pleasant urban environment, directly supporting the Sustainable Development Goals. Critically, while these measures offer significant benefits, their success depends on context-sensitive design and community involvement. The optimal performance of traffic calming strategies can only be achieved with rigorous planning, consistent design principles, and public consultation to ensure that the interventions do not inadvertently create traffic problems. The continuous vandalism of speed bumps, large variations in geometric styles, inconsistent and unsafe design, reporting of major accidents at these measures led to the need of understanding various aspects of traffic calming. The current study reveals several key aspects, namely, scientific aspect, design aspect, cognitive aspect, planning aspect and the area-wise aspect of traffic calming schemes that were researched through a comprehensive literature review. The results have shown that perception is a significant predictor of the driver's compliance and credibility of traffic calming, and by considering it, policymakers can improve the effectiveness of speed-reducing measures that meet the requirements of all road users.

Keywords: traffic calming; speed bump; speed hump; speed table; chicanes; roundabouts.

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Introduction

Since speed is closely linked to accident risk and severity, a significant number of casualties could be prevented if all drivers adhered to speed limits. These limits should be set at safe levels, considering factors such as road function, vehicle class, and design. However, speeding remains a widespread issue, with 40% to 60% of drivers exceeding the limit, and 10% to 20% surpassing it by more than 10 km/h (Economic, 2006). The extent of violations on a given road is influenced by various local factors, including speed limits, road conditions, traffic density, vehicle composition, and enforcement levels, which differ across regions and countries. In India, road traffic injuries (RTIs) have been steadily rising over the past two decades, though the rate of increase has fluctuated. Between 2004 and 2011, road fatalities surged at an annual rate of 6.8%, whereas since 2012, the growth rate has slowed significantly to 0.8% per year. Figure 1 shows number of road deaths and death rate expressed as number of deaths per 100,000 population in India for past 4 decades.

As per the Institute of Transportation Engineers (ITE, 2018), an amalgamation of different physical measures that might alter driver-behaviour, lessen speed uniting itself with cyclists and other non-motorised traffic is known as Traffic Calming. Traffic calming is an effective method for regulating vehicle speeds, particularly in areas where speeds are either excessive or unsuitable for the road's function and usage. The primary reason for implementing traffic calming measures is to enhance safety by reducing accident risks. Although accident numbers on residential roads are typically low and dispersed over a large area, with fluctuating annual rates, traffic calming allows for a comprehensive, area-wide approach to address these isolated incidents systematically. It is a method for addressing traffic issues and creating a secure environment for road users like, drivers, cyclists, pedestrians, and locals on residential streets by reducing the amount of through traffic and the high speed of cars into nearby residential areas. Khademi et al suggested

that the main goals of traffic calming measures are to encourage citizen participation in the planning process and to make streets attractive and safe for walkers and other non-motorized users (Khademi et al., 2013). Traffic calming measures are essential for the traffic speed management systems to be effective. Speed management should be complemented by education and awareness programs to help road users understand the risks associated with excessive speed and the importance of adhering to speed limits. Pennsylvania's Guidelines to Traffic Calming (2012) suggested various speed management techniques (Figure 2).

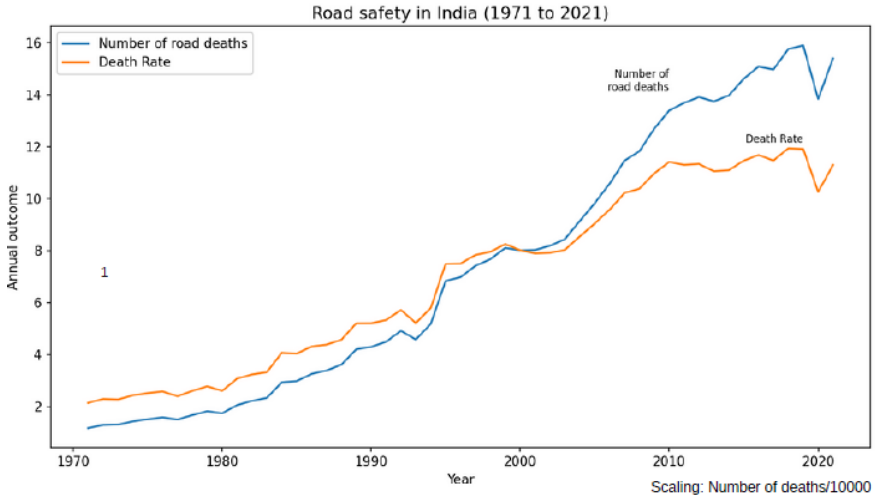

Figure 1. Road deaths from 1971 through 2021 (National Crime Records Bureau, 2022).

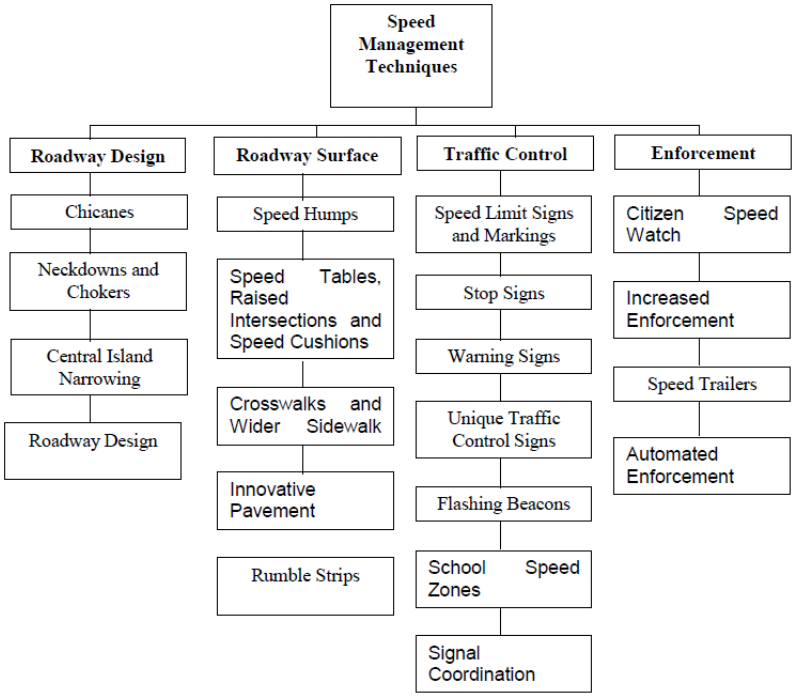

Figure 2. Speed Management Techniques (Transportation, 2012).

Road engineering interventions, such as speed humps and street narrowing, are effective in reducing vehicle speeds in areas where maintaining low speeds is crucial. When implemented consistently, these measures also assist drivers in understanding the road environment and corresponding speed limits. However, despite these efforts, some drivers will still deliberately exceed speed limits, making enforcement a necessary tool to ensure compliance. Although many nations use various traffic calming measures, they lack design guidelines or a methodical implementation procedure (Domenichini et al., 2019). Compliance with speed limits is positively impacted by the credibility of the limit and the design of such measures (Yao et al., 2019). European traffic calming measures are primarily designed for road networks dominated by motor vehicles. However, this approach does not fully align with Indian traffic conditions, which feature a diverse mix of

vehicles, including two-wheelers, bicycles, pedestrians, and non-motorized transport. The differences between Indian and European traffic systems in Organization for Economic Co-operation and Development (OECD) countries are summarised in Table 1.

Table 1. Traffic in India vs OECD Countries (Tiwari et al., 2023).

Feature	India	OECD countries
Modal mix of traffic in urban areas	Two-wheelers, three-wheelers, and non-motorised traffic comprise a much larger share of traffic than cars	Cars are the dominant mode
Modal mix on inter-city roads	Trucks and buses constitute a larger share than cars on most highways. Presence of tractors and non- motorised traffic. Large variation in speeds.	Cars are the dominant mode. No tractors and non-motorised traffic. Little variation in speeds.
Highways passing through townships	Almost all inter-city roads pass through townships and villages. Therefore, all inter-city traffic must interact with local traffic when passing through these areas. This situation is likely to remain the same for quite some time.	The extensive network of limited access highways ensures that most long-distance traffic uses this network. Traffic on inter-city roads passing through townships is generally not long-distance and hence has slightly different characteristics and needs.
Vehicle characteristics	Suspension systems of vehicles and their sizes vary greatly. Thus, horizontal traffic-calming measures like lane narrowing and staggering would have to be re-explored to deal particularly with narrow vehicles. Vertical measures like humps (speed-breakers) would affect cars, motorcycles, trucks, and buses differently.	Since most vehicles are cars or even bigger than cars, horizontal measures are effective. Vertical measures which must be tailored to suit cars, buses, trucks, and two-wheelers are not a major issue in these cases.
Traffic segregation	At present, roads in India have very little segregation of traffic. Traffic- calming measures here should include segregation as one of the important measures.	A large proportion of roads in Europe have segregation of traffic particularly due to the provision of bicycle lanes. This makes traffic-calming measures easier to implement.

Without the right instructions, traffic calming measures may have detrimental effects on automobiles, other road users, and the environment. By slowing down moving cars, speed bumps increase pedestrian safety and lower the likelihood of collisions (Damsere-derry et al., 2020). The added safety that it offers could be appreciated by certain drivers, whereas, if speed bumps are uncomfortable to navigate or are not clearly designated, some drivers may view them to be bothersome which could be perceived negatively for residents and road-users (Ramzan & Iqbal, 2019). Emergency vehicles and motorcyclists can be especially impacted (Pratelli et al., 2011). Hence, it becomes a vital part to also understand people's perception before implementing any kind of traffic calming technique on the respective street.

Transportation patterns, including traffic volumes and speeds, have changed because of changes in land use over time. According to data from the Ministry of Road Transport & Highways (MORTH), India, national and state highways account for 1.94% and 2.97% of all roads, respectively, while rural roads make up 70% of all roads, where over a quarter of all traffic injuries are caused by over-speeding. It is the persistent driving habit that endangers both the people inside the car and other vulnerable road users. Even more troubling is the possibility that these numbers are an underestimate since collisions occurring at traffic calming devices are occasionally included with traffic accidents rather than being documented individually (Jassal, Dhiman, et al., 2025). Without the right instructions, their installation may have detrimental effects on automobiles, other road users, and the environment. By slowing down moving cars, speed bumps increase pedestrian safety and lower the likelihood of collisions. The added safety that it offers could be appreciated by certain drivers, whereas, if speed bumps are uncomfortable to navigate or are not clearly designated, some drivers may view them to be bothersome which could be perceived negatively for residents and road-users. Emergency vehicles and motorcyclists can be especially impacted. Hence, it becomes a vital part to understand people's perception before implementing any kind of traffic calming technique on the respective street.

History

Initially, traffic calming measures were introduced on individual residential streets and neighbourhoods with the primary goal of reducing motorized traffic speeds. The concept was first

developed by Alker Tripp (1938), an Assistant Commissioner of the London Metropolitan Police, who proposed a comprehensive strategy for traffic management. However, his approach did not focus on the specific design aspects of these measures. Tripp's book, Road Traffic and its Control, was published in 1938, followed by a revised edition in 1942, titled Town Planning and Road Traffic (Tripp, 1938), in which he identified road safety and increasing traffic volumes as two critical challenges that needed to be addressed. He suggested that significantly lowering vehicle speeds could rapidly reduce road casualties, stating that the closer vehicle speeds were to 5 or 10 km/h, the better the safety outcomes. Over time, the scope of traffic calming expanded, shifting towards city-wide strategies aimed at reducing motorized traffic while promoting alternative transport modes. This modern approach places greater emphasis on environmental sustainability, urban liveability, and public health, while still recognizing that lower urban car travel leads to significant safety improvements.

The rapid increase in car ownership occurred during the 1960s and 1970s, leading to the realization that urban road networks could not accommodate an unlimited rise in vehicle traffic. The concept of traffic calming first emerged in the Netherlands in the 1960s, as cities sought solutions to manage traffic growth. In their book Speed Control & Transport Policy, Plowden and Hillman (1996) explored the negative impacts of high vehicle speeds, including accidents, excessive fuel usage, emissions, noise, and changes in travel behaviour. One of the earliest traffic calming designs was the 'Woonerven', or 'living yards,' which integrated motorized traffic with non-motorised movement within shared street spaces. By the late 1970s, several communities in the United States had adopted traffic calming principles, while the concept also gained traction in other European nations, Canada, and Australia. However, it took several years for traffic calming measures to gain widespread acceptance worldwide.

Brindle (1991) noted that the term 'verkehrsberuhigung' was coined in German literature in the mid-1970s to describe speed reducing measures implemented on local streets in Germany. Around the same time, concerns were growing across Europe regarding the need to enhance urban street liveability by minimizing the negative effects of motor vehicles. Meanwhile, the Transport and Road Research Laboratory (TRRL) in the UK was actively involved in developing and testing speed control measures, including road humps and speed bumps for residential and parking areas (Hodge, 1992). These trials eventually led to the creation of the Watt's profile (Watts, 1973), which became a significant advancement in traffic calming design. The UK implemented its first traffic calming schemes in the late 1970s, with TRRL conducting experimental trials to assess their effectiveness. These measures came into existence in India around the late 80's, in the form of IRC: 99-1988, which was then revised in 2018 as IRC: 99-2018, 'Guidelines for Traffic Calming Measures in Urban and Rural Areas' (Indian Road Congress, 2018).

Purpose

Traffic calming measures have traditionally been applied to local streets, but their use has expanded to collector roads in primarily residential areas. In some cases, they have also been implemented on streets within downtown business districts, though less frequently. However, as per reports, they are generally unsuitable for arterial roads, as these are designed to support higher speeds and accommodate larger traffic volumes (Jassal et al., 2025). Three major purposes of traffic calming include: Safety, Shared Space and Self-Policing.

Safety

These measures are primarily implemented to control over-speeding on residential roads. These issues can create an unsafe and intimidating environment for pedestrians and cyclists, increasing the risk posed by motorized vehicles. The presence of large commercial vehicles in cut-through traffic further intensifies safety concerns. Additionally, non-local drivers using neighbourhood streets as shortcuts are often perceived to be traveling at higher speeds than residents. By reducing vehicle speeds and managing cut-through traffic, traffic calming measures help enhance both the actual and perceived safety of non-motorized road users, ultimately improving the overall quality of life in the community (Jassal et al., 2024).

Shared Space

Traffic calming interventions serve as community-driven solutions to local traffic concerns identified by residents. However, since streets, sidewalks, intersections, and crosswalks form part of the public transportation network, any modifications must adhere to local safety and design standards. The

implementation of these measures requires review and approval from city officials and, in many cases, elected representatives. A study by (Kosakowska, 2022) highlights that a key goal of traffic calming is to encourage public participation in urban planning and create safer, more accessible roadways for pedestrians and non-motorized users. Neighbourhood groups can collaborate with city planners and engineers to develop well-informed recommendations for traffic and mobility improvements, advocating for their implementation. The approval process typically includes resident surveys and an impact assessment of the proposed project on surrounding areas. The initiation of traffic calming efforts can stem from grassroots community initiatives or be led by city officials when traffic-related concerns are identified.

Self-Policing

Physical measures play a crucial role in traffic calming as they are considered 'self-policing', meaning they naturally control vehicle speeds without requiring constant enforcement. Features like speed humps and roundabouts help slow down motor vehicles, ensuring that neighbourhood traffic goals are more effectively achieved. Traffic control devices like traffic signals, pavement signs and markings, and other regulatory tools designed to usher motorists on the roads. In contrast, traffic calming devices aim to create a balanced street environment, ensuring that both vehicular traffic and other road users can coexist safely through self-enforcing measures

Classıfıcatıon

Traffic calming techniques can be categorised based on enforcement, i.e., Design-enforced (pro-active) and Law-enforced (active). The design-enforced techniques are meant to influence the driving behaviour through physical warnings (Speed humps, rumble strips, speed bumps, speed tables etc.) and visual warnings (road signs and road markings). The law-enforced techniques are influenced through speed cameras and police enforcement. Based on the design, traffic calming measures can be classified as:

Vertical displacement techniques

These techniques are mostly referred to as speed bumps, speed humps, speed table, speed cushions, raised intersections, crosswalks, and rumble strips (Figure 3, 4, 5, and 6). All these measures introduce a vertical deflection that forces oncoming traffic to slow down, as approaching them at high speeds causes significant discomfort for both drivers and passengers. These techniques can be implemented individually or combined with other traffic calming features, resulting in a notable reduction in vehicle speeds.

Figure 3. Typical Speed Bump at an Institute Campus (Jassal & Sharma, 2024b).

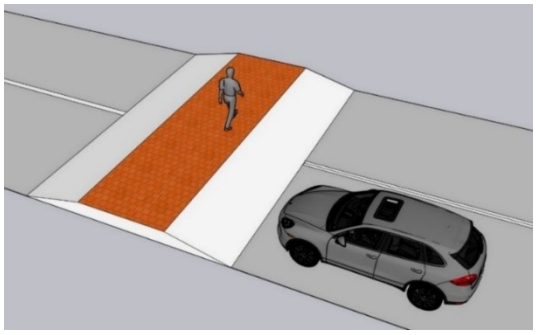

Figure 4. Speed Table at a Dual Carriageway (Jassal & Sharma, 2024a).

Figure 5. Typical Speed Cushion (ITE, 2018).

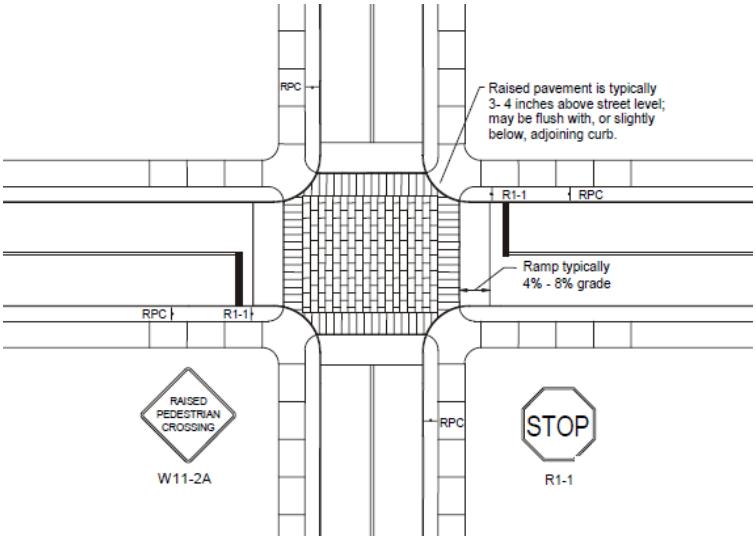

Figure 6. Illustration of a Raised Intersection (Batson, 2004).

Horizontal displacement techniques

These methods reduce vehicle speeds through horizontal deflections, commonly using chicanes, road narrowing, and mini roundabouts (Figures 7, 8, and 9). When applied individually, they typically result in only minor speed reductions. Since these techniques often require vehicles to partially enter the opposing traffic lane, a degree of conflict is unavoidable—which, in fact, serves as the primary mechanism forcing drivers to slow down when approaching these features

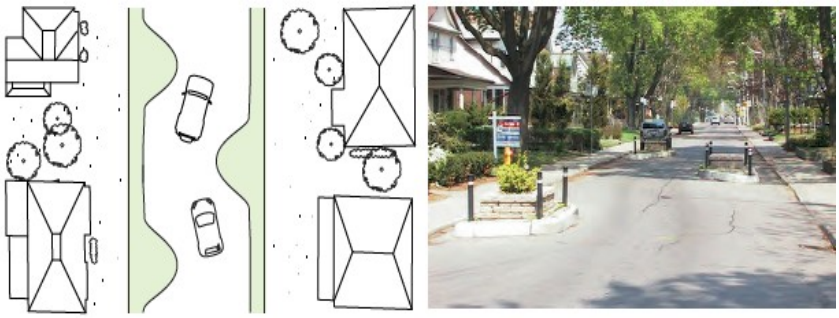

Figure 7. Illustration of a Chicane (Distefano & Leonardi, 2019).

Social aspect

Traffic calming measures would be most effective if such schemes are implemented domain-wise for e.g. hospitals, intersections, national highways crossing a rural or an urban region, school zones, minor roads approaching a major road, curves etc. There is no doubt that road users are being greatly impacted by the increasing number of travel patterns, both in rural and urban locations. Compared to other road users—pedestrians and children in particular—are more prone and vulnerable to road-side hazards. It eventually becomes a pre-requisite to have mandatory traffic calming schemes to avoid danger of pedestrian injury while

walking in an area where high-speed cars are allowed. But it has been observed that the school zones are devoid of any such crossing infrastructure for pedestrians. Furthermore, there are no provisions to define area-wise traffic calming measures for such areas. The current study attempts to also assess risk and eventually suggesting preventive measures and deciding the best suitable area-specific traffic calming scheme for such zones.

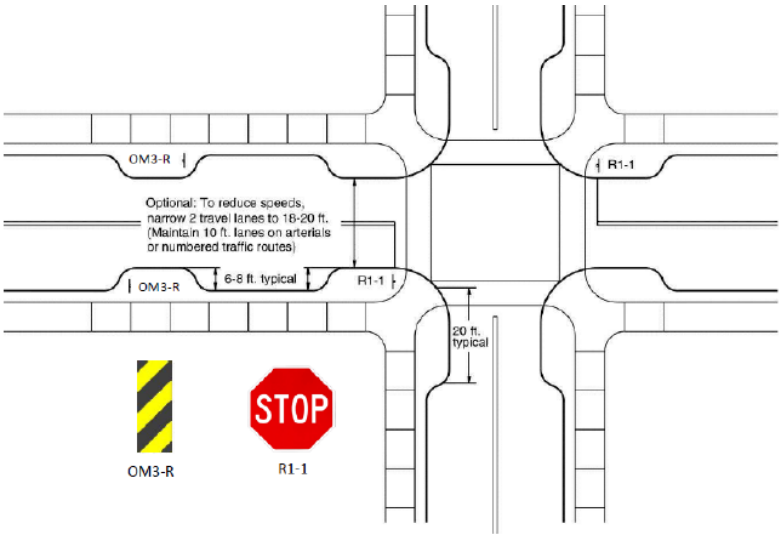

Figure 8. Illustration of Curb extension/Bulb-out (ITE, 2018).

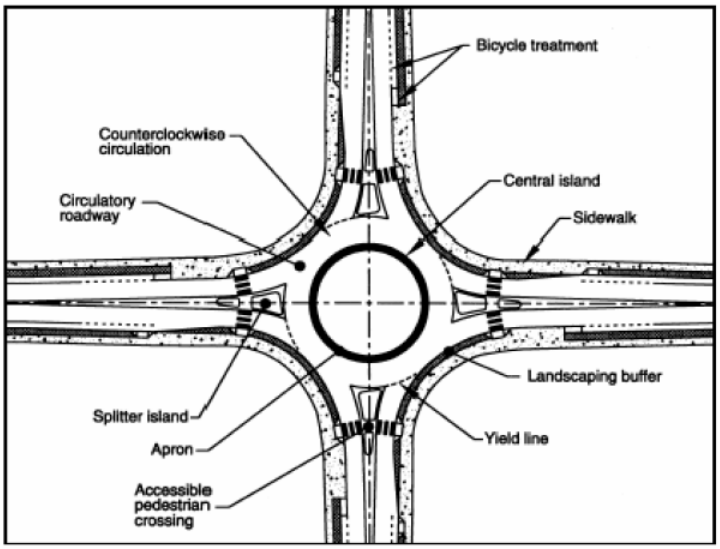

Figure 9. Illustration of a Traffic Circle.

Global aspect

A thorough global study of different countries from American, European, and Asian regions, was taken into consideration. To specify the objectives of the current study, the literature has been categorised based on the concept of different aspects that influence the feasibility, choice, design, and eventually, the implementation of Traffic Calming schemes.

Toronto

Traffic calming guide (2016) in the city of Toronto suggests that traffic calming aims to enhance the well-being of residents and quality of streets where these measures are implemented, while also ensuring reduced vehicle speeds and improved safety for pedestrians and other non-motorized users. Rather than addressing issues on individual streets, traffic calming needs to be approached as a community-specific, to prevent the redistribution of traffic volume and speed concerns to nearby streets (Toronto Transportation Services Division, 2016).

The above-mentioned Warrants/Technical criteria (Table 2) should be met arranged in the form of Yes/No answers, in addition to the technical requirements, such as, Minimum speed, min and max traffic volume, min

block length, transit service etc. Beyond traditional traffic calming measures, additional strategies can be implemented to influence driver behavior and discourage cut-through traffic. Some of these approaches may be applicable to roadways beyond local and collector streets. The feasibility of these options is typically evaluated by Transportation Services' Traffic Operations staff, in coordination with the district office and the Councillor's office (Figure 10).

Table 2. Traffic Calming Guide for Toronto (2016).

Road Classification	Characteristics	Volume (vehicle/day)	Typical Right-of-way Width (metres)	Speed (km/h)	Suitable for Traffic Calming
ocal Roads	• Provide access to properties • Low traffic speed • Generally, no bus routes • Truck restrictions preferred	Less than 2,500	15 – 22	30 – 50	Yes
Collector Roads	• Provide access to properties and traffic movement • Signalized intersections at arterial roads • Truck restrictions permitted	2,500 – 8000	20 – 27	30 – 50	Yes
Minor Arterial Roads	• Traffic movement is a primary function • Some property access control • No "Stop" signs • No Truck restrictions	8,000 – 20,000	20 – 30	40 – 60	No
Major Arterial Roads	• Traffic movement is a primary function • Subject to property access control • Special cycling facilities preferred	Greater than 20,000	20 – 45	50 – 60	No
Expressways	• Traffic movement is a primary function • No property access • Grade-separated intersections (no traffic signals) • Pedestrian and cyclist access prohibited	Greater than 40,000	Greater than 45	80 – 100	No

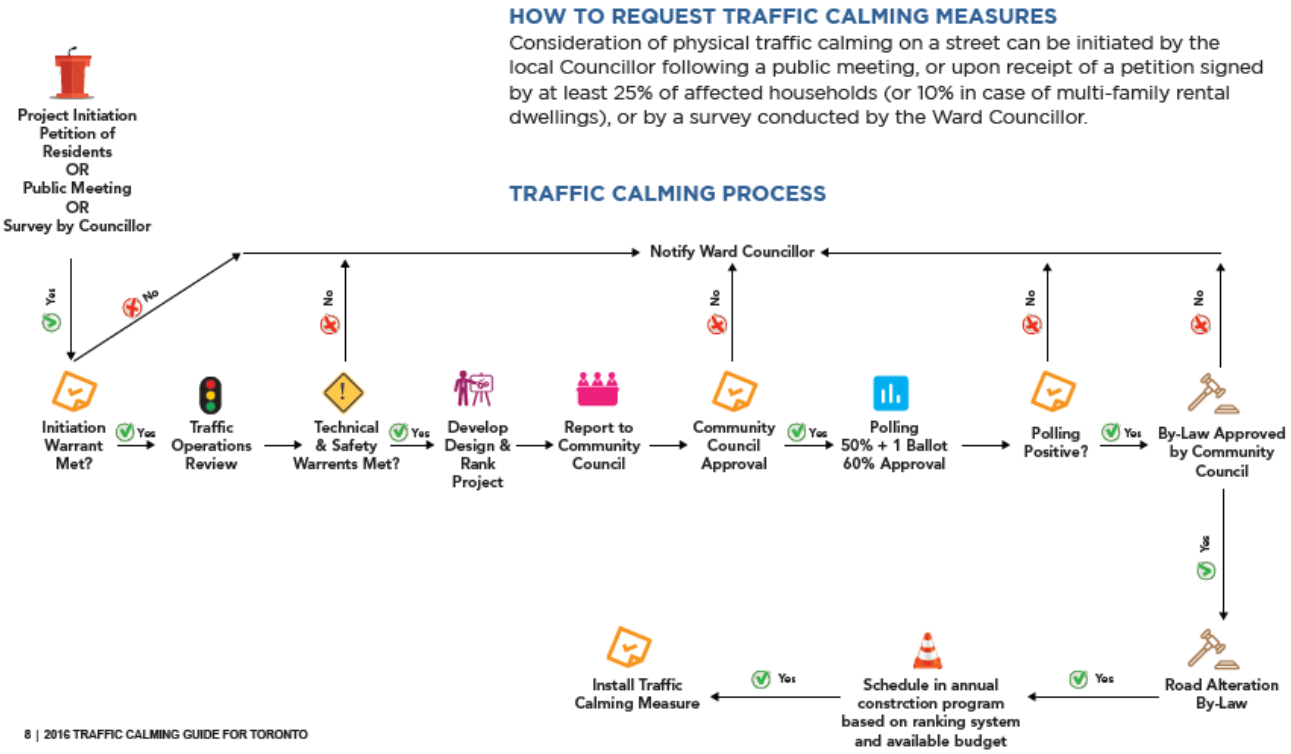

Figure 10. Traffic Calming Process (Source: Traffic calming guide for Toronto, 2016).

Alabama

The 2022 report of the state of Alabama suggested that increased enforcement for vehicle speeding is required for less than 4000 vehicles/day and physical traffic calming techniques for traffic more than that. The ideal, acceptable, and not-acceptable speeds have been mentioned in their guideline (Table 3). Table 4 outlines the speed criteria and suggested traffic calming measures to address speeding concerns. However, no traffic calming interventions are proposed for collector or arterial roads, as indicated on the Street Classification Map, nor for streets with traffic volumes exceeding 4,000 vehicles per day (City of Alabama, 2022).

Table 3. Vehicle Speeds on the Local Streets of Alabama (2022).

Limits	Ideal	Acceptable	Not Acceptable
Average Speed – All Vehicles	0-25 mph	26-30 mph	31-35 mph
85th Percentile Speed	0-30 mph	31-35 mph	36-40 mph
95th Percentile Speed	0-35 mph	36-40 mph	41-45 mph
Percent of Vehicles in 10 mph Pace Speed	70%	60%	50%

Table 4. Recommended Traffic Calming Techniques in Alabama (2022)

85th Percentile Speed above posted speed limit	Traffic Calming Technique Recommended
0 – 5 mph	Not recommended
5 – 10 mph	Street narrowing or surface roughing
10 mph and above	Speed table or combination of techniques

Asheville

During the initial assessment, a prioritization rating system is applied to rank streets based on their need for traffic calming measures. The prioritized list serves multiple purposes for different city departments, with its main objective being to identify streets and areas suitable for traffic calming projects (Burden, 2000). However, resource limitations may result in some areas not being selected or funded for extended periods. Additionally, the development process for a traffic calming project can take several months, leading to further delays for residents. The criteria used for ranking will have different weightings in the rating chart, as outlined in Table 5.

Table 5. Rating Chart for Different Criterion to Install Traffic Calming Solutions.

Criteria	Points	Basis for point assignment
Speed	0 to 40	4 points assigned for every mph greater than 5 mph above the posted speed limit (using the full day 85th percentile speed)*
Volume	0 to 20	1 point for every 200 vehicles per day*
Crash history	0 to 10	1 point assigned for each 0.3 recorded crashes per year per mile of roadway (based on the past three years)
Pedestrian generators	0 to 10	4 points for each elementary or middle school within 500 feet of the project area. 2 points for each other school, bus route, park, or community center within 500 feet of the project area. 2 points should be given if any (not for each) retail, commercial, or other institutional (including churches) uses exist within 500 feet of the project area.
Roadway Geometry	0 to 8	Each street segment will be rated on a scale of 0 to 8 for potentially hazardous roadway geometry and other factors. Factors to be considered include horizontal and vertical curvature, street width, proximity of homes to the street, stopping sight distance, intersection sight distance, and driveway sight distance and geometry.
Residential Density	0 to 7	1 point assigned for every 25 dwelling units per mile.
Sidewalks	0 or 5	5 points assigned if there is no continuous sidewalk on at least one side of the street.
Total Points Possible	100	

*For streets that exhibit cut-through traffic characteristics during specific hours, the following alternative method may be used if it results in a higher score. For speed: 3 points for every mph greater than 5 mph over the posted speed (using the 85th percentile speed calculated during heavy cut-through traffic periods). For traffic volume: 1 point for every 20 vehicles per hour during the peak hour recorded on the street.

Pennsylvania

The 2012 Pennsylvania Traffic Calming Handbook provides a comprehensive overview of commonly used traffic calming devices and practices based on survey findings. To be eligible for traffic calming measures, a road must satisfy minimum traffic volume criteria—specifically, it should have an Average Daily Traffic (ADT) exceeding 1,000 vehicles or a peak-hour count of more than 100 vehicles. The specific requirements vary based on the primary concern: if speeding is the main issue, the 85th percentile speed must be at least 10 mph

above the posted limit before measures are implemented; if cut-through traffic is problematic on a residential street, such traffic should constitute at least 40% of the total traffic volume/hour/direction, with no fewer than 100 cut-through trips recorded in that hour. Since such measures can sometimes be controversial, their implementation typically follows a three-step approach- ensuring a balanced and effective traffic management strategy. During the initial investigation phase, employing a ranking system is valuable for prioritizing the ones meeting the established standards in the study and its compliance process, like Ashville's method. Given the limited funding available, it is unlikely that all proposed traffic calming projects can be implemented. The ranking system, therefore, helps determine the order in which projects should be carried out based on their priority. Table 6 provides an example of a 'Project Ranking System' designed to address the specific needs of the locals.

Table 6. Traffic Calming Project Ranking System.

Criteria	Points	Basis for point assignment
Speed	0 to 30	Extent by which 85 percentile speeds exceed posted speed limit; 2 points assigned for every 1 mph.
Volume	0 to 25	Average daily traffic volumes (1 point assigned for every 120 vehicles).
Crashes	0 to 10	1 point for every crash reported within past 3 years.
Elementary or Middle Schools	0 to 10	5 points assigned for each school crossing on the project street.
Pedestrian Generators	0 to 15	5 points assigned for each public facility (such as parks, community centers, and high schools) or commercial use that generates a significant number of pedestrians.
Pedestrian Facility	0 to 10	5 points assigned if there is no continuous sidewalk on one side of the street; 10 points if missing on both sides.
Total Points Possible	100	-

Ireland

The 2007 Local Transport Note provided detailed information on legislation, design criteria, and installation of signing and lighting, at traffic calming measures in their handbook. A key point highlighted in the report was the recommendation that these undergo safety audit to ensure that the measures themselves do not contribute to accidents (Department of Regional Development, 2007). When implemented appropriately, traffic calming measures can play a significant role in achieving casualty reduction targets, especially for pedestrians and children (Table 7).

Table 7. Factors Used to Determine Priority for Traffic Calming Schemes.

Criterion	Range	Priority Factor
Vehicle speed (mph) (85th percentile)	over 45	12
	41–45	10
	36–40	8
	31–35	6
	26–30	4
	20–25	2
	Under 20	0
Vehicle flow (vehicles/hour) (average for peak hours)	per 100	1
	over 1000	10
Cyclists (average per hour over 4 highest hours in any day	per 10	1
Pedestrians crossing road (pedestrian/km/highest hour over 4 hours in any day)	per 100	3
Number of frontage residents/km	per 100	1
Accident level (personal injury accidents/km/year averaged over 3 years)	per accident	5
	under 1	0
Potentially hazardous locations within scheme	school entrances	6
	bus stops	3
	community centres	3
	doctor surgeries	3
	elderly, nursing homes	3
	hospitals	3
	elderly lunch clubs	3
	nurseries, play groups	3
	post office, local shops	3
	recreation grounds	3

Netherlands

A report commissioned by the Swedish National Road Authority recommended that traffic calming in and around residential areas should focus on discouraging through-traffic while ensuring that the remaining motorized traffic travels at safe and appropriate speeds. In contrast, traffic calming on major urban roads should primarily aim to achieve safe speeds, while city-wide traffic calming seeks to reduce motorized traffic volume by creating safe and attractive alternatives for cycling and walking. In residential and shopping areas, road design should ensure that through-traffic is diverted, and that the remaining motorized vehicles drive at low speeds, yielding to other road users (OECD, 2006). For major urban roads, the potential for traffic calming is more limited. The report also emphasized that the location and design of traffic calming measures are crucial for their success. Firstly, the measures should not distract drivers excessively, as this could cause them to miss important information about the road environment. Secondly, simple and intuitive measures are more likely to be accepted by drivers. Thirdly, if drivers fail to understand the purpose of a measure, they may become frustrated and react negatively. To enhance acceptance, traffic calming measures should be placed in natural locations, such as pedestrian crossings. Finally, these measures must always be highly visible, which can be achieved through proper lighting, colour patterns, and reflective strips. Shiny surfaces that may cause glare when wet should be avoided to prevent sunlight reflections that could blind drivers (Van Schagen, 2003).

CAREC Countries

In August 2024, a manual was prepared under an Asian Development Bank (ADB) technical assistance grant, collectively for 11 member countries belonging to the Central Asia Regional Economic Cooperation (CAREC). The manual comprises of evidence-based opportunities for road safety improvements via highly effective features that help to manage speeds such as speed humps, raised platforms, chicanes, roundabouts, lane narrowing, and gateway treatments, effective speed managing interventions in vehicle technology, in terms of intelligent speed adaptation. The manual suggests that that contrary to common belief, lower speeds generally improve national economies and increase long-term economic growth, because safe speeds reduce the large economic costs of crash deaths and injuries as well as other areas of economic loss. These costs exceed the costs of slower travel.

Many CAREC countries use speed humps but these are not common in many locations where they would be a suitable solution for speeding. Changes to standards and guidelines are recommended to specify the many circumstances where speed humps should be required or at least recommended, rather than allowed (CAREC, 2024). The manual on Traffic calming infrastructure (2024) delivers significant road safety benefits and is recommended for widespread adoption in CAREC countries and elsewhere. Research shows that in lower speed-zoned areas, engineering measures, such as speed humps and speed cushions, are more effective than enforcement. Vertical deflection treatments delivery twice the reduction in injury crashes achieved by speed cameras. Traffic calming should be visible to drivers via signage warnings and/or by visible painting of the traffic calming device. Highly visible gateway treatments with traffic calming measures such as a raised platform, speed hump, and/or lane narrowing are effective and should be adopted at the entry to urban or village areas where the speed limit changes (CAREC, 2024).

Singapore

A 2019 report about ‘Road Safety Approach in Singapore’ was prepared by the staff of World Bank focusing on practices of road infrastructure and road safety engineering. Singapore’s road safety management policies, over a decade now have led to significant improvements in road safety statistics, addressed by the factors related to roadway design, human behaviour, and vehicle characteristics. Certain areas have been designated as Silver Zones and School Zones, where speed management techniques are implemented due to the presence of vulnerable pedestrians, such as elderly individuals and schoolchildren. These measures include a speed limit of 40 km/h, along with appropriate signage, assisted crossings, and safety features like rumble strips (Global, 2019). Traffic calming methods are also used on various streets in Singapore, including the installation of central refuge islands at zebra crossings on undivided two-lane roads. These islands help to narrow the carriageway, encouraging vehicles to slow down. The slightly raised pedestrian crossings act like speed humps, increasing visibility for approaching vehicles. Centre dividers serve to physically separate oncoming traffic, further narrowing the carriageway to encourage slower driving. Physical traffic-calming measures such as road humps are effective in reducing speeds on minor arterial roads, as drivers are alerted

to the presence of the hump and can reduce their speed in advance. Rumble strips are used to alert drivers of potential risk through a vibrating effect, while raised profile markings work similarly, preventing vehicles from deviating from their lanes. These features are particularly helpful for drowsy or distracted drivers, alerting them through vibrations and sounds, thus reducing the risk of collisions (Chng et al., 2022).

Scientific aspect

Webster D.C. (1995) conducted an analysis of humps and chicanes across four schemes implemented on collector streets of the United Kingdom, where daily traffic volumes reached up to 12,000 vehicles. In these schemes, the speed humps were predominantly flat-topped with ramp gradients between 1:10 and 1:15. His study evaluated the effects of these measures on vehicle speeds, traffic flow, and accident rates, and incorporated feedback from emergency services, bus operators, and residents (Webster, 2000). In another study, Lockwood C.R. (1997) used a driving simulator, analysing how drivers navigated through simulated village environments before and after the implementation of traffic calming measures. The recorded speed data was compared to actual speed measurements taken on the real roads that the simulations aimed to replicate (Lockwood, 1997). Mackie A. (1998) assessed the performance of a range of traffic calming interventions—including speed cameras, vehicle-activated signs, flashing signs, and speed zones. His report also reviewed the effectiveness of six 20 mph zones that lacked specific calming measures and compared these with three trial sites that similarly did not incorporate extra traffic calming features (Mackie, 1998). Additionally, Cloke J. et al. (1999) evaluated various traffic calming elements such as humps, cushions, traffic islands, mini roundabouts, gateways, pedestrian refuges, and build-outs. Their report presented data on vehicle speeds, traffic flow, and accident frequencies, while also examining driver behavior, vehicle emissions, air quality, traffic noise, and local resident attitudes toward the implemented schemes (Cloke et al., 1999).

Tiwari and Gupta (2004) studied the effect of traffic calming options on selected corridors of National Highways and State Highways passing through towns and villages and develop guidelines for traffic calming measures. The two principles namely, visual, and physical, are used for reducing speed and further compiled to form speed zones, in and around the town and villages. Gates, humps, speed cushions, platforms, rumble strips, narrowing, staggering, rotaries etc. have been discussed as traffic calming measures for the assigned roads. The speed profile was also formulated (Tiwari, 2004). Hadayeghi, A. et al. (2006) measured the effectiveness of a colourful slurry seal treatment, projected to narrow down the carriageway lanes, to reduce driving speed and volume on specifically local streets. The change in 85th percentile speed was also noted with passage of months and a significant decrease in 24 hour traffic volume was experienced with the study (Hadayeghi et al., 2006). Rahman F. et al. (2007) aimed at providing a foundation for implementing similar principles in Japan and other regions lacking such guidelines. Through a questionnaire distributed across European countries and the United States, 72% of projects prioritized point scoring system, whereas 14% relied on engineering judgments, and 24% on other criteria (Rahman et al., 2007).

Garcia A. et al. (2011) employed traffic microsimulation along with GPS tracking methods to assess how traffic calming devices affect the capacity of cross-town roads. Their study modeled various types and spacing intervals of these devices. By calculating the average delay and road capacity for a given spacing, they discovered that delays increased exponentially as traffic flow rates rose. Depending on the spacing—ranging from 25 to 400 meters—the capacity of a cross-town road varied between 810 and 1,300 vehicles per hour per lane (García et al., 2011). In an investigation, cat-eye reflectors were used as retroreflective safety equipment that may be effectively supplied. Similar cat-eye reflectors in carriageway lanes were being researched in Egypt as traffic-calming and warning devices. Through field speed measurements and an interview-survey with different road users, their effectiveness has been assessed (Hui, 2012). Moreno A. T. (2013) et al. suggested speed profiles as surrogate measures but the evaluation of calming measures and their effectiveness has been limited. They developed a methodology that uses continuous speed profiles on cross-town roads, especially when historical data, or crash and speed data, is unavailable. The study considered two indexes, accumulated speed variations above average speed and other, speed limit. The study found that a spacing of less than 110 meters, deemed optimal in previous research, prevented drivers from significantly adjusting their speeds (Moreno & García, 2013).

Wei (2013) et al. analysed the non-physical measures that help to influence drivers to adjust their driving behaviour and travelling speed suiting the road conditions and the surrounding environment, viz. textured surfacing, variable message signs and speed signs. The study was conducted on 11 locations with 85th percentile speed results to provide an alternative to replace existing bar markings on the road section and

evaluate other measures of traffic calming (Ng & Wei, 2013). Kordani A. A. (2014) demonstrated through simulation that the most crucial geometric factor affecting a vehicle's vertical acceleration on a speed hump is its height. For speed tables, the length of ramp also plays a significant role. In general, flat-topped profiles produce lower dynamic responses than parabolic profiles. However, for especially trucks and cars, sinusoidal profiles generated lower vertical forces at lower speeds (Molan & Kordani, 2014).

Wahed (2017) and colleagues observed that pavement deterioration near speed humps was largely due to their random placement and inadequate engineering justification. In their case study, they collected and analysed visual inspection data to evaluate how speed humps affect road conditions on intercity roads of rural areas. The study examined humps on a two-lane, two-way road connecting two cities, calculating the Pavement Condition Index (PCI) for road stretches across both directions of the hump. They measured each hump's parameters, such as width, height, and the distance from the previous hump, and then used statistical methods to explore the correlations between these characteristics and pavement conditions, developing regression models to represent these relationships (Abdel-wahed & Hassan, 2017). Additionally, traffic calming strategies have been shown to improve safety for vulnerable users—including drivers, cyclists, pedestrians, and neighbourhood residents. Various techniques are now in use, such as physical barriers that redirecting traffic, reducing lane and carriageway widths, and approaches that minimize or eliminate conflict points vehicles and other unsafe road users (Cantisani et al., 2023). Figure 11 illustrates various traffic calming schemes across an urban area

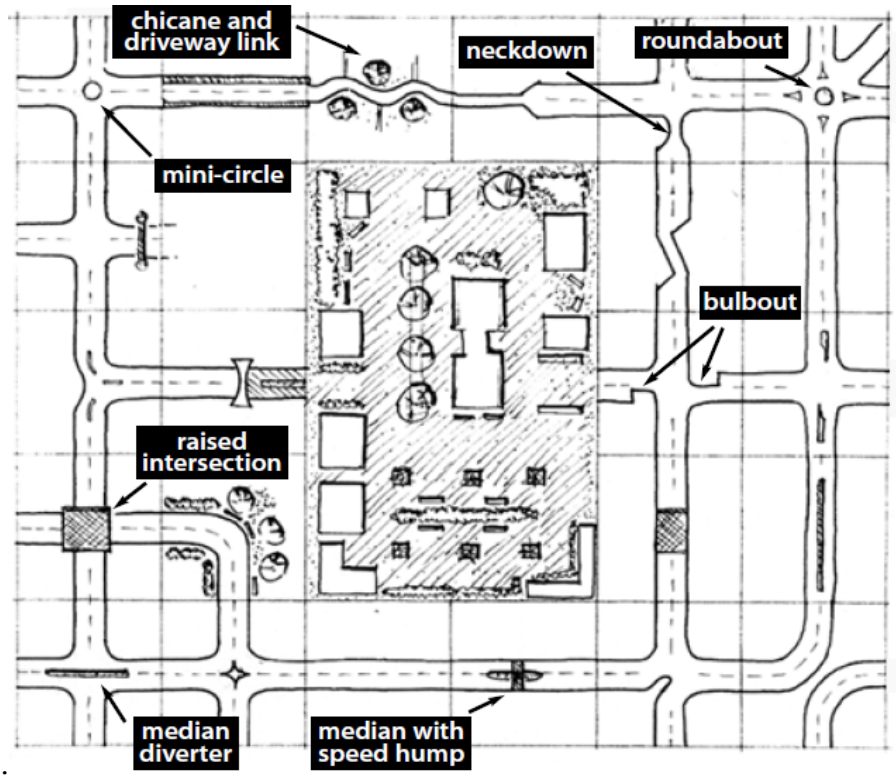

Figure 11. Illustration of Various Traffic Calming Schemes.

In summary, speed humps are formed by elevating sections of the road into circular, parabolic, or sinusoidal shapes, typically measuring between 10–15 cm in height and 4–6 m in length—dimensions that can be adjusted to achieve the desired speed on the street. Similar in purpose, speed cushions incorporate openings for wheels so that larger vehicles like buses can pass without disruption while still slowing down smaller cars. In contrast, speed tables feature a flat surface and are generally 6–9 m long; when these are combined with pedestrian crossings at intersections or mid-block locations, they are referred to as raised crossings. Enhancements to pavement appearance—such as using coloured or patterned asphalt, concrete, or pavers—not only add visual interest but also help other traffic calming features stand out. Additionally, pedestrian refuge islands can effectively narrow traffic lanes on even compact streets, organizing traffic at intersections or blocking access at critical points. Mini roundabouts, which are circular islands at intersections, serve to lower speeds and guide vehicles around the island rather than straight across the junction. Moreover,

narrowing lanes tends to reduce speeds and minimize accidents by limiting the available right-of-way, encouraging drivers to be more cautious; the space saved can then be repurposed for pedestrian areas, cycling lanes, or green infrastructure. Finally, reducing corner radii helps to slow vehicle turning speeds and shortens pedestrian crossing distances.

Cognitive aspect

Greek municipalities of Kalamaria and Larissa conducted a questionnaire-based study with high school students in grades one through three. Student's perceptions of the level of traffic safety in the area around schools, the causes of their feelings of unsafeness, their familiarity with the Highway Code, participation in activities associated with traffic education, their thoughts on traffic calming measures, and the modes of transportation they used to travel to and from school were examined by (Basbas & Kokkalis, 2007). A research study examined how young riders behaved and how they felt about traffic safety, and it made recommendations on how to create a book of safe riding instructions that would help them avoid risky circumstances. A questionnaire study of 300 people who rode different kinds of two-wheelers under 150 cc was done to ascertain their risk-taking behaviour and attitude toward traffic safety. The statistical findings show that riding behaviour and views of respondents toward traffic safety change significantly according on the geography (rural, suburban, and urban), age and gender and the journey distance. This aids them in identifying, averting, and managing hazards in challenging traffic circumstances. The findings support the notion that teenagers' riding behaviour and risk awareness are influenced by factors such as geography (urban, suburban, and rural areas), demographics (gender and age), and trip distance (Luu et al., 2021).

Another research study used a sample of 367 Japanese drivers to perform a questionnaire study. The findings demonstrated that although most drivers thought about exceeding the 30 km/h speed limit to shorten their journey time, they tended to have favourable opinions about obeying the limit and understanding the risks associated with doing so. The study found evidence in favour of public awareness programs and social campaigns, from the perspective of drivers, roadways should be built to make that speed limit more credible (Dinh & Kubota, 2013). In one of the studies, 500 Indonesian driver respondents with prior experience crossing Indonesian roads freely took part. On highways, Indonesian drivers travelled at an average speed of 90.1 km/h. According to the respondents' demographic information, different jobs exhibit different speeding behaviours. The model demonstrates that cognitive attitude, emotional attitude, and non-legal punishments all have a direct impact on speed intention (Qaid et al., 2022).

Using a questionnaire, a research study was conducted to assess the credibility of the present legal speed limit in various contemporary UK road situations as well as the discrepancy between the suggested speed limit and the driver's self-reported speed. The survey's findings showed that the perception of speed and speed restrictions was influenced by road layout and the surroundings along the side of the road. Drivers tended to drive at greater speeds, the higher the speed limit they believed to be**.** For a specific rural single carriageway, another study examines the link between the variables of risk perception, speed limit believability, and compliance with speed limit (Yao et al., 2020). Structural Equation Modeling (SEM), Exploratory factor analysis (EFA) and Confirmatory factor analysis (CFA) were used to analyse a developed conceptual model. The key findings indicate that, on the cognitive side, thinking about one's own problems and chores, as well as roadside advertisements, and looking at advertisements and the surrounding environment, have the most detrimental effects on how drivers perceive important changes in the traffic environment. Whereas, drivers who pay attention to pedestrians and traffic signals while also considering their speed, traffic laws, and other drivers are more likely to notice significant changes in the traffic environment (Cvahte Ojsteršek & Topolšek, 2019). Certain techniques must be adapted to achieve the goals to manage efficient traffic flow characteristics and ensuring safety of all road users around vulnerable areas

Conclusion

Urban traffic calming measures play a crucial role in enhancing road safety, reducing vehicle speeds, and improving the quality of life in cities. This review highlights the effectiveness of various physical and technological interventions, including speed humps, chicanes, raised intersections, and smart enforcement systems. While these measures have shown significant positive outcomes, their success depends on context-sensitive design, community acceptance, and continuous evaluation. Integrating data-driven approaches, such as UAV monitoring and simulation tools, can further refine implementation strategies. Moving forward,

a balanced combination of engineering, enforcement, and education will be essential for creating safer and more sustainable urban mobility systems.

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