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Review

Beyond Speed Reduction: A Systematic Literature Review of Traffic-Calming Effects on Public Health, Travel Behaviour, and Urban Liveability

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Abstract: Traffic calming has emerged as a key urban strategy to reduce vehicle speeds and mitigate road traffic risks, with increasing recognition of its broader implications for public health, human behaviour, and urban liveability. This systematic literature review examines the multifaceted impacts of traffic-calming measures—from speed limit reductions to physical infrastructure and enforcement-based interventions—by synthesising findings from 28 peer-reviewed studies. Guided by the PRISMA framework, the review compiles research exploring links between traffic calming and outcomes related to public health, behaviour, and urban quality of life. Research consistently indicates that such interventions reduce both the frequency and severity of collisions, improve air and noise quality, and promote active mobility. These effects are shaped by user perceptions: non-motorised users tend to report higher levels of safety and accessibility, whereas motorised users often express frustration or resistance. Beyond safety and environmental improvements, traffic calming has been associated with greater use of public space, stronger social connections, and enhanced environmental aesthetics. The findings also show that key challenges may affect the effectiveness of traffic calming and these include negative attitudes among drivers, mixed outcomes for air quality, and unintended consequences such as traffic displacement or increased noise when interventions are poorly implemented. Overall, the findings suggest that traffic calming can serve as both a public health initiative and a tool for enhancing urban liveability, provided that the measures are designed with contextual sensitivity and supported by inclusive communication strategies.

Keywords: traffic calming; public health; travel behaviour; liveability; quality of life; speed limits

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1. Background and Introduction

High vehicle speeds constitute one of the key causes of severe traffic collisions worldwide and are responsible for significant human losses, incapacitating injuries, and property damage. Apart from the social costs, road collisions also have an enormous economic impact on local and national economies due to many hours of lost productivity, medical expenses for treatment of those severely affected by traffic injuries, and reconstruction of damaged properties and infrastructure [1]. Due to the high impact of vehicle speeding on public health through the mechanism of road collisions, addressing its negative effects constitutes a key priority for local and national authorities. This is particularly important in

places where the most vulnerable groups of the road user population, such as pedestrians and cyclists, live, work, and spend most of their time. For instance, the probability of a human life loss, if a collision occurs between a car and a pedestrian, is five and a half times more likely if the impact speed is 30–40 mph instead of 20–30 mph [2]. Given that even a relatively small reduction in average vehicle speed can significantly affect collision outcomes [3], it is crucial to implement measures that encourage motorised vehicle drivers to adopt lower driving speeds. In this context, one of the most effective and widely employed approaches to reducing speeds and subsequently mitigating the associated collision risks is the implementation of traffic-calming measures. The latter can address multiple dimensions of speed behaviour that may bear hazardous safety implications, including both speeding (i.e., exceeding posted speed limits) and generally high vehicle speeds (even when within the legal speed limit). Both dimensions of speed behaviour are particularly critical for vulnerable road users.

Traffic calming constitutes a transport management approach aimed at reducing the negative effects of motor vehicle use for motorists, cyclists, and pedestrians, and due to its diversified impact, it is recognised as an important transport intervention with significant impact on public health [4–6]. Traffic-calming measures can be classified into various categories, as they may target both infrastructure and drivers, specifically focusing on road design as well as driving behaviour and perception. In this context, the following three key categories of traffic calming are typically distinguished: physical interventions, psychological interventions, and enforcement-based measures [7–10]. Key physical traffic-calming measures aim at directly reducing vehicle speeds through physical restrictions on vehicle movements; typical examples include speed humps and bumps, speed tables, raised pedestrian crossings, lane narrowing, median raised islands, and rumble strips. Psychological measures (e.g., road narrowing or a coloured road surface) focus on altering drivers' behaviour by encouraging them to comply with the posted speed limits or adopt even slower speeds. Lastly, enforcement-based measures typically include both automated and manual control systems—such as speed cameras and police patrols—which are designed to detect traffic violations and provide feedback or deterrence to drivers. Lower speed limits, specifically 20 mph (or 30 kph) speed zones and limits, constitute a key dimension of traffic calming, which may combine principles from all the previous categories in order to gradually foster a "self-enforcing" environment of safe speeds. While the review primarily focuses on retrofitting traffic-calming measures applied to existing road infrastructure, some of the included studies also examine redesign or reconstruction efforts in which traffic calming was introduced. The systematic review of studies focuses on the outcomes of such interventions, irrespective of their implementation phase.

The role of traffic-calming measures in reducing the frequency and severity of road collisions is well established and thoroughly examined in the existing scientific literature. A wide array of previous studies has articulated the positive outcomes of such measures and strategies, especially in terms of eliminating collisions and associated casualties [11–16]. The collision mitigating mechanism of traffic calming is rooted in its capacity to organically encourage car drivers to use lower speeds when traversing collision-prone areas of urban and rural environments. Such collision-prone areas include crowded city centres, neighbourhoods on the city outskirts, and main/central roads crossing through villages.

Apart from the road safety benefits, traffic calming bears positive effects on the environment and public health, which are primarily related to the reduction of air and noise pollution [17–19]. The environmental benefits mainly stem from the lower energy consumption of vehicles at lower speeds [19]. However, some drivers tend to avoid traffic-calmed parts of the road network and use alternative routes instead. Such route deviation may reduce the flow of motorised vehicles on the traffic-calmed roads, thus reducing the associ-

ated exhaust fumes and noise annoyance. The propensity of drivers to avoid calmed routes may result in phenomena such as migration of traffic volume or speeding behaviour in non-calmed areas [20]. Despite the availability of previous research on this topic, further investigation is needed to clarify additional aspects and achieve a more comprehensive understanding of the phenomenon of traffic migration.

Despite their widely acknowledged benefits, several challenges need to be addressed so that local authorities can systematically integrate traffic-calming measures in their transport and mobility policies. At the same time, it is essential to strengthen public understanding of their value for road safety and public health. One key challenge is that traffic-calming interventions sometimes fall short of fully achieving their primary goals or have significant side effects that frustrate and alienate residents. For example, speed bump installations sometimes cause more noise near residences than there was before their installation [21]. Additionally, some interventions, such as 20 mph (30 kph) speed zones, are relatively new or unexpected to some categories of road users, leading to increased resistance against their implementation, thus triggering negative attitudes in residents and road users [22].

The pathway towards addressing these challenges is predicated on the thorough evaluation of traffic-calming implementation. While the primary goal of evaluating traffic-calming measures is to assess their impact on vehicle speeds, the indirect effects on quality of life—particularly those related to behavioural changes and local liveability—have not been sufficiently explored to date. Previous research [23] has indicated that the liveability of traffic-calmed areas can be significantly influenced by such measures. Interestingly, most studies have focused on public health outcomes, with limited and inconsistent attention given to the impact on well-being, despite its crucial role in determining the quality of life for residents and road users.

In this context, the motivation for this study arises from the need to gain a deeper understanding of how various traffic-calming measures impact local liveability, as well as the mechanisms through which these effects are generated. The review does not focus exclusively on 30 km/h (20 mph) speed limits, nor solely on well-being-related outcomes, but rather considers a broad range of traffic-calming interventions—physical, regulatory, or perceptual—and examines their effects across three interrelated domains: public health, behavioural change, and perceived liveability. However, as previously mentioned, the impacts on liveability aspects are interrelated with public health and behavioural outcomes of traffic calming on all road users. While the safety-related impacts of traffic calming are widely recognised in the previous literature, these are retained in this review study, not separately, but under the lens of public health aspects that are interrelated with liveability. This is particularly due to their influence on perceived safety, comfort, and overall urban quality of life.

Among other traffic-calming measures, particular consideration will be given to lower speed limits, which have been widely established in urban and suburban areas over the last few years. On this aspect, previously published comprehensive reviews have investigated the effects of 20 mph interventions on public health [23,24]. A previous literature review also attempted to associate general traffic-calming measures with aspects of public health and travel choices such as safety, obesity, and active travel [25]. Of these studies, only one sought to identify evidence relating to the impact of liveability [23]. However, this was accomplished again under the prism of public health. Considering the knowledge gap with regard to the mechanism underpinning these interrelated effects of traffic calming, the objective of this study is to provide a comprehensive review of the integrated impacts of different types of traffic calming on public health, the behaviour of road users, and the liveability of calmed areas.

2. Materials and Methods

2.1. Overview

To identify the knowledge gaps relating to the impact of traffic calming on liveability, behaviour, and public health, a systematic literature review is conducted in this study. A systematic literature review is an independent method of scientific analysis aiming to identify and evaluate all relevant studies and available research findings on a topic in order to derive conclusions about the existing knowledge on the topic and the aspects that require further research in the future. In other words, the purpose of a systematic literature review is "*to clarify the state of existing research and the implications that should be drawn from this*" [26]. To conduct a systematic literature review, it is necessary to decide which studies will be included in the analysis based on specific, well-defined criteria. The specification of appropriate inclusion criteria is crucial for ensuring the relevance of the studies and their consistency with the scope of the review. These criteria were defined in line with previous systematic reviews on similar topics [23,27] and are presented below:

- Must be published in the English language, at any time, in a peer-reviewed academic journal.
- Must be a primary study or a review study. Commentaries have been excluded.
- Should not include research cases of fully pedestrianised zones or traffic calming targeted at car-only road segments.
- Must investigate qualitative or quantitative associations between traffic calming and at least one of the three outcome domains—public health, behavioural change, or liveability. Studies were included in the review if they either directly addressed liveability or examined any of the other two domains (i.e., public health or behavioural outcomes) while also providing insights into liveability; such insights could be provided either directly (e.g., through assessments of quality of life or use of public space) or indirectly (e.g., via environmental indicators, user perceptions, or behavioural adaptation). Studies that focused exclusively on safety outcomes (e.g., collision or injury rates) without contextual data, perceptual dimensions, or broader interpretations relevant to liveability were excluded from the review.

2.2. Scoping Review, Data Sources, and Search Strategy

To ensure that the systematic review followed a methodologically sound approach, a comprehensive literature search was conducted using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [28]. The full search strategy in line with the PRISMA process is presented in Figure 1, and the keywords used in each step of the systematic review are presented in Figure A1 (Appendix A). The bibliographic databases used for the search and identification of relevant studies were the following: Web of Science, Scopus, and Google Scholar. The literature search covered studies published between 1980 and 2025, reflecting the time period during which traffic-calming interventions have been developed and widely implemented in urban transport policy. The initial search through the bibliographic databases resulted in 2131 scientific papers, and subsequently, three rounds of screening followed. At first, papers were separated based on the relevance of their title to the topic of the study, with this process narrowing the results to 131 outputs. The next stage of screening was based on a review of abstracts, leading to 22 papers for full-paper review. Lastly, those papers were scrutinised for the relevance of their full body content, and 17 articles were considered to fulfil the inclusion requirements. In addition to these studies, 10 additional studies were considered through an additional bibliographic search at a second stage, and after a thorough examination of their content, were included in the final review. The key reason for excluding numerous studies was the lack of direct association with public health or liveability outcomes. In

this context, studies strictly focusing on the impacts of traffic calming on vehicle speeds or traffic volume were excluded from this systematic review. Also, given the methodological diversity of the included studies—ranging from observational designs to perception-based surveys and theoretical frameworks—outcome domains were coded based on whether they were investigated, discussed, or conceptually addressed, regardless of the strength or statistical significance of the findings.

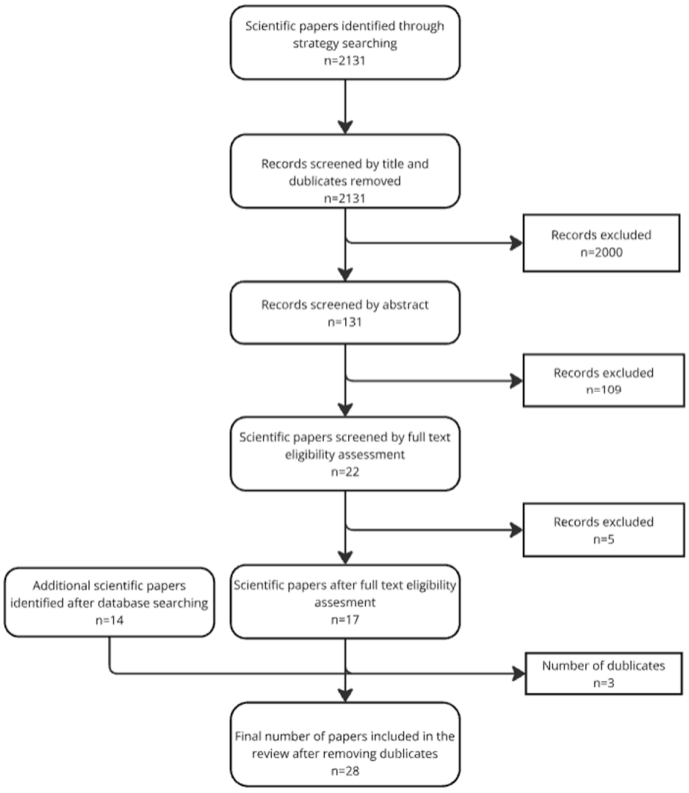


Figure 1. PRISMA flowchart.

2.3. Data Extraction

A thorough review of the selected studies allowed for the extraction of multi-dimensional data, enabling a structured comparison of their content and findings based on consistent criteria. This approach facilitated a more coherent synthesis of the available literature. The extracted data covered the study design, study location, type of intervention, and the results. The results were categorised into three key outcome dimensions that define the scope of the review: public health, behavioural change, and liveability. Each dimension was further classified into components based on key concepts that were identified upon the analysis of the reviewed studies. Specifically, the components of the public health dimension included collisions and casualties, air pollution, and noise pollution. Active mobility and mode choice formed the behavioural change dimension, whereas the liveability outcome consists of impacts related to public space, social capital, and environmental attractiveness of the traffic-calmed areas. Furthermore, a distinction was made (Table 1) based on whether the intervention consisted of a single type of traffic-calming measure (*Single type of Traffic-calming measure*, S.T.C.) or was part of a more integrated approach (*Integrated Approach*, I.A.). Tables 1 and 2 present the characteristics and results of the reviewed studies in a detailed manner: Table 1 organises the information by individual study, while Table 2 structures it according to the key components of public health, behavioural change, and liveability.

Table 1. Characteristics and results of the reviewed studies in chronological order of publication.

	Study	Area of Implementation—Participants	Intervention	Findings *								
				Public Health			Behavioural Change			Liveability		
				Collisions and Casualties	Air Pollution	Noise Pollution	Active Mobility	Mode Choice	Social Behaviour	Public Space	Social Capital	Environmental Attractiveness
1	Morrison et al. (2004) [4]	A small, deprived neighbourhood on the outskirts of Glasgow, UK	(I.A.) Traffic-calming interventions in a community	✓			✓			✓		
2	Leden et al. (2006) [29]	Community centre of Storuman, Sweden	(I.A.) Reconstruction of arterial road	✓			✓	✓		✓		
3	Lee and Moudon (2008) [30]	Seattle, King County, Washington State, USA	(I.A.) Change in neighbourhood design, including traffic-calming measures				✓					
4	Nitzsche and Tscharaktschiew (2013) [31]	'Average' German metropolitan area	(S.T.C.) 30 km/h speed limit policies					✓		✓		
5	James et al. (2014) [8]	Eastern Massachusetts, USA	(S.T.C.) Speed limits on local roads reduced from 30 mph to 25 mph	✓	✓							
6	Toy et al. (2014) [32]	Citizens of Bristol, England	(S.T.C.) 20 mph signs-only speed limits						✓			
7	Wen Hu & Anne T. McCartt (2016) [33]	School zones Montgomery County, Maryland, USA	(S.T.C.) Cameras on residential streets with speed limits of 35 mph or lower and in school zones	✓								
8	Tapp et al. (2016) [34]	Drivers and residents in Great Britain	(S.T.C.) 20 mph limits						✓			
9	Villarroel et al. (2016) [35]	Santiago, Chile	(S.T.C.) Different colour on bike lanes	✓								
10	Jones and Brunt (2016) [36]	Welsh cities, UK	(S.T.C.) 20 mph zones and limits	✓	✓							
11	Hinckson (2016) [37]	Children and adolescents and parents in Auckland schools, New Zeeland	(S.T.C.) School Travel Plan (STP) initiatives				✓				✓	

Table 1. *Cont.*

	Study	Area of Implementation—Participants	Intervention	Findings *								
				Public Health			Behavioural Change			Liveability		
				Collisions and Casualties	Air Pollution	Noise Pollution	Active Mobility	Mode Choice	Social Behaviour	Public Space	Social Capital	Environmental Attractiveness
12	Bachok et al. (2017) [38]	Selected road spots in Malaysia	(S.T.C.) road humps installation			✓						✓
13	Turner et al. (2018) [19]	Edinburgh, UK	(S.T.C.) Citywide 20 mph speed limit	✓	✓		✓	✓		✓		
14	Shwaly et al. (2018) [39]	Residents of Kafr El-Sheikh city as a typical model in Egyptian cities	(S.T.C.) Speed hump installations	✓	✓	✓	✓			✓		
15	Scheiner et al. (2019) [40]	Parents of primary school in Lünen, North Rhine-Westphalia, Germany	(I.A.) Analysis of existing measures and installations				✓	✓		✓		
16	Weiand et al. (2019) [41]	Residents of the city of Potsdam, Germany	(I.A.) A series of traffic measures (including traffic-calming measures)				✓	✓				
17	Cleland et al. (2020) [23]	Relevant scientific studies	(I.A.) 20 mph zones and limits	✓								
18	Lawrence et al. (2020) [42]	City of Yarra, Melbourne, Australia	(S.T.C.) Speed limits were reduced to 30 km/h in the trial area	✓						✓		
19	Balant and Lep (2020) [43]	Residents of a neighbourhood in Ljutomer, Slovenia	(I.A.) Comprehensive traffic-calming interventions	✓			✓			✓	✓	
20	Milton et al. (2021) [3]	Edinburgh and Belfast, UK	(S.T.C.) 20 mph speed limit initiatives	✓								
21	Sdoukopoulos et al. (2021) [20]	City centre in Serres, Greece	(I.A.) A mix of many traffic-calming measures	✓	✓							
22	Cleland et al. (2021) [22]	Belfast, UK	(S.T.C.) 20 mph (32 km/h)	✓	✓	✓	✓	✓		✓	✓	
23	Hunter et al. (2022) [44]	Belfast city centre, UK	(S.T.C.) 20 mph schemes	✓								

Table 1. *Cont.*

	Study	Area of Implementation—Participants	Intervention	Findings *								
				Public Health			Behavioural Change			Liveability		
				Collisions and Casualties	Air Pollution	Noise Pollution	Active Mobility	Mode Choice	Social Behaviour	Public Space	Social Capital	Environmental Attractiveness
24	Williams et al. (2022) [45]	Edinburgh city residents, UK	(S.T.C.) 20 mph (32 km/h) speed limit on 50% to 80% of Edinburgh city streets	✓			✓					
25	Brink et al. (2022) [18]	Residents in a district of Zurich, Switzerland	(S.T.C.) Lowering the speed limit to 30 km/h on street sections that exceed the legal noise limits	✓		✓						✓
26	Chang et al. (2022) [46]	Singapore	(I.A.) Traffic-calming measures in neighbourhoods of Singapore for seniors	✓						✓		
27	Doomah and Paupoo (2022) [21]	Local community in Mauritius	(S.T.C.) Four speed-table combinations at high-risk road segments			✓	✓					
28	Haroon et al. (2025) [47]	Doha City, Qatar	(S.T.C.) Speed bumps and humps installations			✓						

* The ✓symbol indicates that the study investigated or discussed the relationship between traffic calming and the outcome domain. It does not necessarily imply a demonstrated association or causal effect. Table key: (S.T.C.) single-type traffic calming; (I.A.) integrated approach.

Table 2. Classification of reviewed studies by component and outcome.

Dimensions	Components	Relevant Studies	Summative Outcomes
Public Health	Collisions and casualties	James et al. (2014) [8]; Turner et al. (2018) [19]; Milton et al. (2021) [3]; Wen Hu & Anne T. McCartt (2016) [33]; Hunter et al. (2022) [44]; Shwaly et al. (2018) [39]; Williams et al. (2022) [45]; Lawrence et al. (2020) [42]; Villarroel et al. (2016) [35]; Cleland et al. (2021) [22]; Balant and Lep (2020) [43]; Morrison et al. (2004) [4]; Chang et al. (2022) [46]; Brink et al. (2022) [18]; Leden et al. (2006) [29]; Sdoukopoulos et al. (2021) [20]; Jones and Brunt (2016) [36]; Cleland et al. (2020) [23]	**Benefits**: ↓ injuries, ↓ fatalities, ↓ average speed. **Drawbacks**: ↑ inattention, ↑ wrong overtaking, ↑ risky pedestrian behaviour
	Air pollution	James et al. (2014) [8]; Turner et al. (2018) [19]; Shwaly et al. (2018) [39]; Cleland et al. (2021) [22]; Sdoukopoulos et al. (2021) [20]; Jones and Brunt (2016) [36]	**Benefits**: ↓ average speeds, ↓ car use and smoother traffic flows (less accel. and braking), ↓ air pollutants **Drawbacks**: ↑ traffic congestion, ↑ air pollution
	Noise pollution	Doomah and Paupoo (2022) [21]; Shwaly et al. (2018) [39]; Cleland et al. (2021) [22]; Bachok et al. (2017) [38]; Brink et al. (2022) [18]; Haroon et al. (2025) [47]	**Benefits**: ↓ average speed ↓ noise exposure **Drawbacks**: ↑ noise pollution if speed humps/bumps installed without plan
Behavioural Change	Active mobility	Turner et al. (2018) [19]; Doomah and Paupoo (2022) [21]; Shwaly et al. (2018) [39]; Williams et al. (2022) [45]; Weiand et al. (2019) [41]; Cleland et al. (2021) [22]; Scheiner et al. (2019) [40]; Balant and Lep (2020) [43]; Morrison et al. (2004) [4]; Lee and Moudon (2008) [30]; Hinckson (2016) [37]; Leden et al. (2006) [29]	**Benefits**: ↑ walking and cycling
	Mode choice	Turner et al. (2018) [19]; Nitzsche and Tscharaktschiew (2013) [31]; Weiand et al. (2019) [41]; Cleland et al. (2021) [22]; Scheiner et al. (2019) [40]; Leden et al. (2006) [29]	**Benefits**: ↑ modal shift away from car use towards more sustainable travel modes
	Social behaviour	Tapp et al. (2016) [34]; Toy et al. (2014) [32]	**Benefits**: ↑ compliance with traffic-calming intervention
Liveability	Public space	Turner et al. (2018) [19]; Nitzsche and Tscharaktschiew (2013) [31]; Shwaly et al. (2018) [39]; Lawrence et al. (2020) [42]; Cleland et al. (2021) [22]; Scheiner et al. (2019) [40]; Balant and Lep (2020) [43]; Morrison et al. (2004) [4]; Chang et al. (2022) [46]; Leden et al. (2006) [29]	**Benefits**: ↑ quality of street-crossing conditions, ↑ accessibility, ↑ security, ↑ pedestrian ease to move around
	Social capital	Cleland et al. (2021) [22]; Balant and Lep (2020) [43]; Hinckson (2016) [37]	**Benefits**: ↑ socialisation with friends and neighbours
	Environmental attractiveness	Bachok et al. (2017) [38]; Brink et al. (2022) [18]	**Benefits:** ↑ local quality of life in terms of safety, noise and air quality

Table key: ↑ increase in; ↓ decrease in.

3. Results

3.1. Theoretical Pathway to Impact

To better understand the mechanisms underpinning the impacts of different traffic-calming measures on public health and behavioural and liveability outcomes, a comprehensive theoretical pathway was developed and leveraged for the analysis of the reviewed studies and discussion of findings. This pathway is presented in Figure 2. The direct impacts, mediating factors, and the components of the outcomes included in the theoretical pathway were drawn from the synthetic analysis of the reviewed studies. Overall, the implementation of traffic-calming measures leads to two primary direct impacts: a reduction in vehicle speeds and a decrease in traffic volume within the affected areas [48]. These changes influence the perceptions and attitudes of both motorised and non-motorised road users. For non-motorised users, lower speeds and reduced traffic volume can enhance feelings of safety and comfort, encouraging more active and eco-friendly travel behaviours. Meanwhile, motorised users may adjust their driving habits and attitudes in response to the altered traffic environment. Together, these mediating factors help translate the direct effects of traffic calming into broader public health, behavioural, and liveability outcomes, as illustrated in the theoretical pathway.

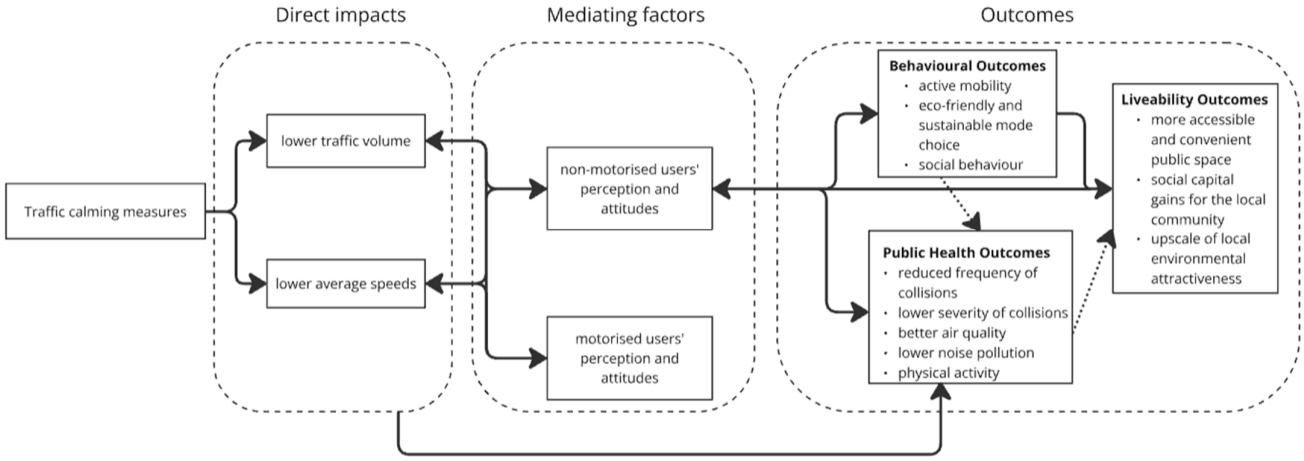


Figure 2. A logical pathway between traffic-calming measures and behavioural, public health, and liveability outcomes.

Starting with motorised road users, some may perceive traffic-calming measures as beneficial, offering enhanced road safety, reduced driving stress, and a stronger sense of community. When these positive perceptions take hold, they can contribute to reinforcing the intended benefits of traffic calming, particularly in relation to public health outcomes such as fewer collisions, lower injury severity, and improved air and noise quality. However, for a different segment of motorised users, traffic-calming measures may introduce perceived constraints on their typical driving routines, potentially leading to feelings of frustration and inconvenience. This frustration is a key factor contributing to a reduction in traffic volume, as regular drivers seek to avoid routes with these measures in place, thereby diverting to alternative routes. Importantly, changes in traffic volume may occur regardless of attitudinal change. For example, drivers may reroute or reduce trip frequency due to objective constraints, such as discomfort, delay, or inconvenience imposed by physical road measures, even if their attitudes toward the intervention remain negative. As such, behavioural adaptation can take place through both perceptual and situational mechanisms. Furthermore, some motorised users may perceive traffic calming as a barrier to their usual travel habits. In such cases, their resistance can hinder the realisation of the

positive outcomes associated with traffic calming, particularly those related to public health and liveability.

On the opposite end, according to findings from the reviewed studies, the pathway towards the positive outcomes of traffic calming is subject to the perceptions and attitudes of non-motorised users. For the latter, potential shifts in perceptions may pave the way for favourable impacts on public health and local liveability. It should be noted that such positive impacts are mainly triggered by behavioural changes; positive perceptions towards traffic calming can encourage several forms of active mobility (e.g., walking cycling) and promote the use of environmentally friendly mobility options.

Such behavioural shifts can also exert indirect impacts on public health. Beyond the direct public health benefits of reduced speeds and traffic volume—such as fewer collisions, casualties, and lower levels of air and noise pollution—traffic calming can also promote additional health gains through increased physical activity, driven by greater uptake of active travel. When this shift is accompanied by the adoption of more sustainable transport modes and social norms that encourage more cautious and responsible driving, it can significantly enhance local liveability. These behavioural changes often translate into increased demand for accessible, user-friendly public spaces and interventions that improve the environmental quality and attractiveness of neighbourhoods and city centres. The attractiveness of calmed areas can be potentially influenced by improvements in environmental conditions, particularly air quality and ambient noise levels; while these factors fall within the realm of public health, they can potentially cause a positive, spillover effect on urban liveability. For example, quieter, cleaner streets may encourage greater use of curbside spaces and pedestrian areas, leading to increased social interactions. This, in turn, can enhance social capital, which constitutes a key determinant of quality of life and local liveability [49].

As shown in Figure 2, the public health outcome is interrelated with user perceptions, especially for the non-motorised users. The bi-directional arrow highlights a potential feedback loop: improved public health outcomes—such as safer streets and cleaner air—can positively influence perceptions and behaviours, making active and sustainable modes of transport more appealing. This can reduce car dependency and further reinforce public health gains, creating a virtuous cycle of mutually reinforcing benefits. On the opposite end, negative perceptions among both motorised and non-motorised users could undermine the effectiveness of traffic calming, posing barriers to their public health and potential.

Key findings from the reviewed articles were analysed and linked to each of the three outcomes and their respective components. Table 2 presents a detailed mapping of the reviewed articles to each outcome and its components, along with a brief summary of the observed impacts for each outcome component. The findings of the review studies will be discussed under the prism of the developed theoretical pathway. This approach also helps to identify which relationships illustrated in Figure 2 are not clearly supported in the existing literature, thereby highlighting directions for future research. Compared to previous conceptual models—such as the programme theory developed by Turner et al. (2018) [19], which focused specifically on 20 mph speed limits and was informed by stakeholder consultation and qualitative synthesis—our proposed pathway builds upon a broader empirical base. It is derived from a systematic review of 28 peer-reviewed studies encompassing a wide range of traffic-calming interventions, outcome domains, and urban contexts, and it incorporates both linear and feedback dynamics between factors.

3.2. Public Health

3.2.1. Collisions and Casualties

The introduction of traffic-calming measures on a road segment affects the driving behaviour and perceptions of all motorised vehicle users travelling through it, typically leading to lower speeds, increased caution, and a driving style more considerate toward other users [15]. These direct impacts—lower vehicle speeds and traffic volume—play a pivotal role in shaping the perceptions and behaviours of both motorised and non-motorised users, resulting in a variety of beneficial outcomes.

One of the most significant public health benefits of traffic-calming measures is the reduction in both the frequency and severity of collisions. For example, in Eastern Massachusetts, reducing the speed limit from 35 mph to 30 mph resulted in an average speed decrease of 1.8 mph, preventing approximately 2200 collisions, 18 fatalities, and 1200 injuries annually [8]. Similarly, camera-enforced speed limits in Montgomery school zones reduced fatal crashes by 19.4% and overall crashes by 26.6% on nearby roads [33]. In Belfast, a 20 mph speed limit intervention led to small but notable reductions in road traffic collisions and casualty rates, with continued reductions in vehicle collisions observed up to three years post-implementation [44].

These reductions in collision frequency and severity illustrate the pathway from lower average traffic speeds to improved public health outcomes, showing that slower traffic leads to fewer and less severe collisions. This pathway of impact is further supported by a 30 km/h speed limit trial in the City of Yarra, Melbourne, which showed reductions in average speeds, severe injury risks for pedestrians, and a spillover effect of improved safety in surrounding areas [42]. In Serres, Greece, traffic calming significantly reduced traffic flow by 45.2% in the intervention area and reduced collisions by 57.9%, while adjacent roads saw a 7% increase in traffic and a 25.7% reduction in collisions [20], which may suggest that adjacent roads benefited indirectly (in terms of collisions) from reduced speeds or that calmer conditions led to improved driver behaviour more broadly. An array of additional studies on 20 mph zones highlights their effectiveness in reducing the number and severity of collisions and casualties [23]. While many studies document statistically significant reductions in collisions, others report declines that, although observable, did not reach statistical significance.

Lower average speeds also give drivers more time to react to unexpected situations, increasing their ability to decelerate in time and avoid potential collisions. This not only reduces the likelihood of serious or fatal injuries but, through the expectation of safer roads, encourages motorised vehicle drivers to comply with legal speed limits. Although this compliance can initially cause frustration as drivers adjust to slower travel times, it can lead to changes in traffic volume with fewer vehicles on calmed roads, thereby decreasing the likelihood of hazardous incidents between pedestrians and cars. For instance, in Ljutomer, Slovenia, comprehensive traffic-calming measures were implemented through a full redesign of an entire neighbourhood. These included a 30 km/h speed limit on the main (transit) street and a 10 km/h limit on the side (access) streets, the installation of a speed hump at the junction between the footpath and the road, and strategic carriageway narrowing using plantings, planters, benches, playground equipment, and parking spaces. Entry points to the neighbourhood were also narrowed to further calm traffic. Following the implementation of these measures and the redesign of the area, the neighbourhood experienced a nearly one-third reduction in through traffic and peak-hour flow alongside significant decreases in passenger car speeds and the number of collisions [43], underscoring the potential of area-wide design interventions to alter both volume and safety outcomes in a synergistic manner.

However, the local community's perceptions often do not fully recognise the benefits of lower speeds. Studies in Belfast and Edinburgh in the UK found that some participants believed lower speeds could lead to increased driver inattention and potentially more collisions due to higher pedestrian and cyclist activity [3,19]. Concerns included drivers focusing more on their speedometers or mobile phones and pedestrians being more likely to walk into the street, potentially increasing collision rates [22]. For instance, in Kafr El-Sheikh, Egypt, 35% of participants in a study evaluating speed humps believed that humps could result in collisions, primarily due to improper overtaking, especially when humps were poorly designed or inappropriately located [39]. Similarly, a survey in Edinburgh, Scotland—a pioneer city in implementing a citywide 20 mph speed limit in urban areas across the UK—suggested that while collisions and casualties decreased, perceptions of road safety risks did not improve as expected; this highlights a gap between actual safety improvements and public perceptions [45].

Finally, another key aspect of the benefits of traffic calming in terms of public health is the promotion of physical activity through the encouragement of walking and bicycling. However, the specifics of this mechanism will be explored in greater detail later in the study, within the section on behavioural change.

3.2.2. Air Pollution

Chronic exposure to low air quality and pollutants such as particulate ambient air pollution (AAP), particulate matter (PM), and nitrogen dioxide has been linked to an increased risk of respiratory and cardiovascular diseases [50]. These health impacts translate into societal burdens through lost productivity and higher healthcare costs for national systems [51]. Such environmental conditions are commonly found in areas with heavy car dependence and significant motorised traffic [52].

The use of traffic-calming measures in dense city centres and urban areas can significantly improve local air quality. By directly reducing vehicle speeds and traffic volume, these measures modify driving behaviour and traffic flow, which constitute key factors influencing air quality outcomes. For instance, a traffic-calming intervention in the centre of Serres, Greece, led to a 15% to 29% decrease in fuel consumption, greenhouse gases, and air pollutant emissions along the traffic-calmed streets. However, this intervention also led to a 10% increase in emissions in adjacent areas, potentially due to migration of traffic from traffic-calmed areas [20]. The findings of this study illustrate the direct impacts of traffic calming on driving behaviour and vehicle emissions, as well as the importance of considering spillover effects when spatially evaluating the outcomes of traffic calming.

The primary mechanism for these improvements is that motor vehicles travelling at lower and more stable speeds experience fewer acceleration, deceleration, and braking manoeuvres. This more consistent and steady traffic flow reduces fuel consumption and emissions, acting as a mediating factor that leads to better air quality [17]. For example, a citywide 20 mph speed limit in Edinburgh resulted in a modal shift away from car use, smoother traffic flow, and fewer instances of acceleration and braking, all contributing to less air pollution [19]. Similar previous studies have also shown that driving at lower speeds results in lower air resistance and kinetic energy, which subsequently reduces overall energy requirements and fuel consumption [53]. Specifically, reducing traffic volume in traffic-calmed areas leads to lower fuel consumption and fewer emissions from vehicle combustion engines, which are major contributors to urban air pollution. In the Serres (Greece) case study, traffic calming led to an overall 45.2% reduction in traffic flow, although there was a small 7% increase in traffic in adjacent areas [20]. Consequently, local air quality improves, benefiting residents, pedestrians, and visitors who perceive a cleaner environment [54]. Such impacts clearly demonstrate that improvements in air quality can

positively influence the perceptions of non-motorised users, fostering further changes in behaviour and amplifying benefits to public health and liveability, as illustrated in Figure 2.

However, the relationship between traffic calming and air quality is not universally positive and can vary across different contexts and traffic-calming implementations. In Massachusetts, USA, it was projected that reducing speed limits from 30 to 25 mph could lead to more congested traffic, potentially increasing air pollution since vehicles are typically most fuel-efficient at speeds between 40 and 50 mph [8]. This suggests that under certain conditions, the direct impact of reduced speed limits may give rise to negative mediating factors such as increased congestion, which can, in turn, deteriorate air quality. In Wales, UK, where a blanket 20 mph speed limit has been implemented on all restricted roads since September 2023, it has been observed that the differences in NO_2 concentrations between areas with and without a 20 mph speed limit were insignificant [55].

Focusing on the perceptual implications in terms of air quality, 68.6% of respondents in Kafr El-Sheikh, Egypt believed that the extensive installation of speed humps increased environmental pollution due to higher exhaust emissions [39]. Similarly, a 20 mph speed limit intervention in Belfast, UK, led to perceptions of increased air pollution due to more frequent braking and accelerating of vehicles [22]. These perceptions highlight how community responses can vary, influencing the perceived outcomes of traffic-calming measures.

Furthermore, a study on the potential impact of 20 mph speed limits in Welsh cities suggested mixed outcomes: while deaths attributed to nitrogen dioxide (NO_2) exposure could increase by 63, with 753 years of life lost, deaths related to particulate matter (PM2.5) may decrease by 117, corresponding to a reduction of 1400 years of life lost [36]. This indicates that while certain pollutants may increase due to specific traffic-calming measures, others may decrease, showing the complex nature of the impact and associated outcomes of traffic calming on air quality. These mixed findings indicate that while traffic calming can improve local air quality by reducing traffic volume and smoothing traffic flow, its effectiveness can be influenced by local conditions and the unique design of each intervention.

3.2.3. Noise Pollution

In dense urban areas, noise pollution from motor vehicles often exceeds the upper legal limits defined by the World Health Organisation (WHO). This excessive noise is harmful to pedestrians and local residents, leading to sleep disturbances and a variety of health issues. Traffic-calming measures offer significant benefits by not only reducing vehicle speeds but also decreasing noise pollution, thus contributing to improved public health and enhanced liveability.

Motor vehicles are the primary source of noise annoyance in urban areas. By implementing traffic-calming measures such as reduced speed limits and traffic management strategies, the background noise in urban environments can be significantly diminished. For instance, a study conducted in Zurich, Switzerland, focused on a 30 km/h speed limit intervention in street sections exceeding legal noise limits. This intervention led to average noise exposure reductions of 1.58 dB during the day and 1.33 dB at night [18]. These reductions are crucial as they enhance the quality of life for urban residents by creating quieter and more peaceful environments. These observed impacts also illustrate the unidirectional influence of public health improvements on urban liveability, as depicted in the theoretical pathway (Figure 2).

However, the effectiveness of traffic-calming measures in reducing noise pollution depends heavily on the approach and types of measures used. When primarily vertical deflection measures (such as speed bumps) are used, they can sometimes lead to increased noise levels due to the abrupt acceleration and deceleration of vehicles. For example, a perception study on Mauritius found that various types of speed tables caused inconvenience

to road users in terms of noise and vibration [21]. Similarly, the previously mentioned study in Kafr El-Sheikh, Egypt, revealed that 73.6% of respondents believed that speed humps generated additional noise as vehicles passed over them [39]. Also, a recent study in Qatar quantified the acoustic effects of speed humps and speed bumps, showing increased noise levels associated with such installations compared to control areas [47].

Furthermore, in a 20 mph speed limit intervention in the city centre of Belfast, UK, some respondents anticipated increased noise pollution, even though the study did not quantify the proportion of participants expressing this concern [22]. A theoretical overview on road hump effects on traffic noise suggested that both the dimensions and placement of humps significantly influence noise levels [38]. Increased noise is often observed near humps due to acceleration, deceleration, and aggressive driving behaviours, particularly with heavy vehicles or those with louder exhaust emissions [38]. These findings indicate that while traffic-calming measures can enhance liveability by fostering quieter environments, their implementation should be carefully considered to avoid unintended consequences that may exert negative influences on users' perceptions.

Connecting these findings to the theoretical pathway presented in Figure 2, traffic-calming measures exert a multifaceted impact on urban environments. By improving air quality and reducing noise pollution, these measures directly contribute to better public health outcomes and enhanced liveability. The observed perception of quieter, safer streets encourages more non-motorised transportation modes, such as walking and cycling, further supporting the core objectives of traffic-calming initiatives. Lower noise levels make streets more inviting for active travel, improving both the perceived and actual usability of these modes [54].

3.3. Behavioural Change

3.3.1. Active Mobility

The introduction of traffic-calming measures in urban residential districts encourages drivers of motorised vehicles to select lower speeds when travelling through local streets. In this way, the speed differential between motorised and non-motorised vehicles is reduced [19], thus bearing safety benefits to the communities. Consequently, some drivers may choose to avoid these routes, leading to reduced traffic volume and contributing to safer, quieter neighbourhoods. Observations of reduced average speeds and lower traffic volume are supported not only by scientific research but also by the lived experiences of local residents and pedestrians. A survey conducted in Seattle, USA, highlighted that the primary environmental barriers to walking and cycling include excessive traffic (39.0%), dangerous street-crossing conditions (19.5%), a lack of bike lanes or trails (29.0%), and insufficient street trees, benches, and proper lighting [30]. Addressing such barriers is essential for promoting active travel. In this context, research on the effectiveness of coloured bike lanes revealed that yellow-coloured lanes significantly enhance visual saliency, thereby improving cyclists' perception of safety [35]. These more favourable conditions for active travel (e.g., cycling walking) set the stage for a greater sense of perceived safety among local residents and pedestrians. As a result, individuals are more likely to choose walking or cycling over driving when moving around their neighbourhoods. This shift towards active mobility not only helps individuals meet their recommended daily goals for physical activity but also integrates exercise into their everyday routines, promoting overall public health [56]. Walking and cycling, recognised as effective public health strategies, are associated with lower rates of obesity and mortality [57,58]. In this context, the behavioural shift towards more active and sustainable travel modes fosters synergistic effects with public health, potentially contributing to better physical health and well-being, as also illustrated in Figure 2. This is one of the key reasons why the previous literature increasingly frames

traffic calming not merely as a set of traffic control measures but as a form of public health intervention [44,48]

Empirical findings support the benefits of traffic-calming measures for safety under the lens of active mobility. A 20 mph city centre speed limit intervention in Belfast led to perceived improvements in cyclist safety [22]. In Lünen, Germany, traffic calming was associated with higher odds of children cycling to and from school [40]. In Potsdam, Germany, a trial of traffic-calming measures aimed at reducing motorised traffic and promoting the use of bicycles and public transport. Weiand et al. [41] found that respondents anticipated improvements in their mobility patterns due to emerging synergies between active travel and public transport, as well as expectations for better air quality. In Ljutomer, Slovenia, a comprehensive traffic-calming scheme led to 37% of the population walking more often and 27% cycling more often after the redesign of an entire neighbourhood in light of an area-wide, comprehensive traffic-calming scheme [43]. Another study in a small, deprived neighbourhood on the outskirts of Glasgow found that 20% of respondents walked more in the area after the implementation of a neighbourhood-scale traffic-calming scheme, including five sets of speed cushions, two zebra crossings with adjacent railings, and the installation of parking bays [4].

In summary, traffic-calming interventions help create safer, more inviting streets for pedestrians and cyclists by reducing vehicle speeds and limiting through traffic. These changes encourage residents to incorporate walking and cycling into their daily routines, supporting healthier lifestyles and helping to reduce health risks linked to physical inactivity. While the connection between active travel and public health is well established [25], note that there is still limited direct evidence linking traffic-calming measures to increases in physical activity. This highlights the need for further research into the complex and multi-dimensional effects of traffic calming on travel behaviour and public health.

3.3.2. Mode Choice

As far as the behavioural component of mode choice is concerned, it is important to note that, apart from the possible adoption of active mobility, traffic calming can also lead to shifts in the overall mode choices of residents in the calmed area. Interestingly, previous research has also outlined potential mechanisms for identifying modal shifts away from car use in light of 20 mph speed limits, which could, in turn, affect air quality [19]. Also, we found indications of changes in both mode and route choice, as lower speed limits may make travelling by car less attractive for urban residents, mainly in favour of public transport [31]. Drawing information from the 20 mph city limit intervention in Belfast, UK, a large group of road users advocated that the speed limits constitute just a single area of improvement for the complex transport system, and many more changes are required to instigate not only a modal but also a lifestyle change; more substantial improvements of public transport services need to be at the heart of such changes (e.g., cheaper fares, more frequent and better connections) [22]. Traffic calming can also influence school travel mode choices. For instance, a survey conducted in a small Swedish village examined how modifications to the driving code and the implementation of traffic-calming measures along an arterial road affected perceptions of safety and accessibility for school travel. Through face-to-face interviews and questionnaires, the study found that the proportion of children driven to school by car decreased from 37% before the traffic-calming intervention to 21% afterwards [29].

3.4. Liveability

3.4.1. More Accessible and Convenient Public Space

The introduction of traffic-calming measures in urban residential districts brings about significant changes in traffic dynamics, pedestrian safety, and overall neighbourhood liveability. As previously discussed, lower average speeds and reduced traffic volume in traffic-calmed areas foster a safer and more appealing environment for walking and cycling. These changes influence the perceptions of pedestrians and cyclists, contributing to a sense of safety and comfort that makes the streets feel more pedestrian-friendly and accessible. When vehicles travel at speeds closer to human scales, pedestrians feel more comfortable crossing streets and accessing local amenities such as stores, cafes, and green spaces [59]. For instance, the citywide 20 mph speed limit intervention in Edinburgh, Scotland, improved street-crossing conditions, allowing vulnerable groups to judge vehicle speeds more accurately and feel more confident when crossing the streets [19].

In Lünen, Germany, a study found that narrow pavements increased the likelihood of car use among children travelling to and from school, highlighting the importance of adequate pedestrian infrastructure in supporting active travel [40]. Similarly, in Ljutomer, Slovenia, the previously mentioned comprehensive traffic-calming scheme (which included the renovation of footpaths and planting of trees) significantly improved residents' daily lives by making public spaces more accessible and pleasant [43]. In Singapore, the Silver Zone scheme, designed to promote road safety for seniors, was highly valued by respondents for making neighbourhoods safer and more equitable for all users [46]. Focusing on interactions between different types of road users, a survey in Sweden examining the effects of traffic-calming measures found that an intervention on an arterial road significantly increased the proportion of drivers yielding to child pedestrians—from 32% to 72%—thereby enhancing accessibility and safety [29]. However, it also highlighted mixed effects, such as high curb stones reducing accessibility for some users (e.g., elderly users, users with mobility or vision impairment). Furthermore, a public evaluation of speed humps revealed that while they effectively calm traffic, they can also damage surrounding pavements, impacting pedestrian convenience [39]. Overall, traffic-calming measures reclaim space from motorised vehicles for pedestrians, creating a perception of safer, more accessible, and convenient public spaces. However, special care should be taken for users facing physical or perceptual challenges when using public spaces, as non-inclusive design of physical infrastructure can create the opposite effect, that is, reducing accessibility and convenience rather than enhancing them.

3.4.2. Social Capital: Socially Active Neighbourhoods

Traffic-calming measures help reclaim public spaces from motorised traffic, transforming streets into more liveable, people-centred environments. By fostering a sense of safety and freedom of movement, these interventions encourage residents to embrace walking as a primary mode of everyday mobility, ultimately enhancing quality of life in urban neighbourhoods. As people spend more time outside their cars and within their neighbourhoods, they engage more frequently in social interactions, fostering a sense of community. Interestingly, in Ljutomer, Slovenia, 28% of residents reported spending more time socialising with neighbours upon the implementation of traffic-calming measures [43]. Similarly, in Belfast, UK, the 20 mph city centre speed limit intervention led to increased outdoor leisure activities and greater willingness among parents to let their children play outside [22].

In New Zealand, children participating in an active travel school plan enjoyed socialising with friends during their journey to school, highlighting the social benefits of such initiatives [37]. Studies have shown that areas with pronounced car dependence, heavy

traffic, and high speed limits often suffer from reduced social interactions compared to neighbourhoods with comprehensive traffic-calming measures, which foster more active and socially vibrant communities [60]. Furthermore, a lively area with a visible presence of familiar pedestrians enhances the sense of security, contributing positively to the overall well-being of residents [42].

While the exact mechanisms by which traffic-calming measures enhance social activity and inclusion are not fully understood, findings from several studies support their positive impact on community engagement and social inclusion. However, empirical research on the potential of traffic calming for strengthening community bonds and social capital is still limited, rendering this a dimension that warrants further investigation in future research.

3.4.3. Upscale of Local Environmental Attractiveness

The systematic review showed that addressing air and noise pollution through traffic calming significantly improves the liveability and attractiveness of neighbourhoods. This finds further support in the indirect impact of traffic calming on liveability through the mechanism of behavioural changes and public health improvements, as shown in Figure 2. According to previous findings, the upscale of the environmental attractiveness of the calmed area is primarily subject to observed improvements in traffic conditions, air quality, and ambient noise.

Interestingly, the area-wide 20 mph speed limit scheme in Edinburgh was identified, upon a thorough evaluation, to foster a quieter, more pleasant environment without the disruption of speeding cars, making it easier for older and younger people to navigate the urban road infrastructure [19]. Dense urban areas with heavy car traffic are often characterised by excessive noise and poor air quality, which can diminish the appeal of these spaces for walking, socialising, or spending time with family and friends. Therefore, implementing comprehensive traffic-calming interventions can improve air quality and reduce noise pollution. In Zurich, a 30 km/h speed limit on noisy street sections led to lower annoyance and less sleep disturbance among residents [18]. These improvements stem from reduced average speeds, steadier traffic flows, and fewer vehicles travelling through the area, shaping an overall perception of a healthier and quieter local environment.

In summary, traffic-calming measures have the potential to significantly enhance the liveability of urban residential areas. By reducing vehicle speeds and traffic volume, they improve pedestrian safety, accessibility, and overall convenience. These measures also support social interaction, foster a sense of community and cohesion, lower environmental pollution, and encourage active modes of transport. However, the current literature offers limited insight into how traffic calming can be integrated with broader urban regeneration initiatives—an area quite promising for further enhancing the attractiveness and functionality of calmed neighbourhoods.

4. Discussion

4.1. Overview of Impacts

The purpose of this systematic review is to investigate how different variants of traffic-calming measures impact public health and the behaviour and well-being of road users, as well as the overall liveability of the calmed area. While reducing speed limits is the most common intervention examined, it is essential to recognise the wide range of other physical, psychological, and enforcement-based interventions assessed, which are often used in combination to magnify their impacts.

Starting with the impact on public health, there is clear evidence that traffic-calming measures reduce both the frequency and severity of vehicle collisions, thus enhancing road safety for both motorised and non-motorised users. Traffic volume tends to decrease in

intervention areas, with some traffic migrating to adjacent routes or areas [20]. Despite increased traffic on these routes, the overall crash rates often remain lower than pre-intervention levels. However, concerns persist among both drivers and pedestrians that these measures might inadvertently increase inattention to pedestrians, as drivers may focus on navigating the traffic-calming features rather than carefully inspecting the surrounding environment, potentially resulting in lower levels of situational awareness [22]. Such concerns highlight a gap between actual safety improvements and the perceived safety among street users, emphasising the need for enhanced public awareness and education about the benefits of traffic-calming measures. This gap also showcases the mediating role of perception (as shown in Figure 2) when it comes to the public health implications of traffic calming.

Beyond collision and injury prevention, air and noise pollution were identified as key components of impacts relating to public health. The review showed that traffic-calming interventions generally result in positive outcomes for local air quality [20]. The promotion of a smoother driving style with fewer accelerations and decelerations (steady vehicle flow) has the potential to reduce fuel consumption and emissions of crucial air pollutants (such as NO or particulate matter) and greenhouse gases [19,36]. However, public perception often diverges from these findings, confirming again the inter-relationship between perceptions and actual outcomes [22,39]. Many road users believe (either due to deliberate misinformation or lack of awareness) that traffic-calming measures increase congestion and pollution, with some advocating for higher speed limits (40–50 mph/65–80 km/h) as more environmentally friendly [8]. This misconception underscores the need for effective communication strategies to convey the true environmental benefits of traffic-calming measures and gain further public support.

With regard to the impact of traffic calming on noise pollution, the findings of the review suggest that traffic-calming measures typically reduce noise pollution by lowering vehicle speeds, leading to less noise annoyance [18]. These effects were more pronounced in dense urban areas. However, calming measures involving vertical deflection can increase noise levels due to abrupt changes in instantaneous speeds and non-suitable speed hump/bump dimensions [21,38,39]. This duality underscores the context-dependent nature of traffic-calming outcomes, where physical design and placement play a crucial role in determining net environmental effects. The effects of traffic calming on noise pollution in rural areas remain unclear, necessitating further research to determine their overall impact.

As expected, the analysis of the reviewed studies reinstated the significant potential of traffic calming for behavioural change. Traffic-calming measures are strongly associated with increased active mobility, encouraging more people to walk and cycle [4,29,43]. This shift has significant public health benefits, integrating physical activity into daily routines and enhancing the overall health and well-being of a community. Enhanced perceptions of safety and accessibility in traffic-calmed areas support these behavioural changes, which, in turn, foster a healthier, more active population [22,40]. While the association of traffic calming with the adoption of active mobility is clear, its association with the overall mode choice of users is less definitive. This distinction is important, as influencing a broader modal shift beyond walking and cycling requires structural integration with public transport systems—something that most studies have not addressed. Previous studies have suggested that making car travel more time-consuming and less appealing encourages the use of public transport [61]. However, this behavioural mechanism cannot be truly verified unless traffic-calming measures are complemented by intermodal mobility policies and road infrastructure that promote public transport [31]. Overall, direct empirical insights linking traffic-calming measures with increased use of public transport, micromobility, or shared mobility remain limited. This highlights the need for further research to better

understand how traffic-calming influences mode choice, particularly in the context of integrated, sustainable, and carbon-neutral urban mobility strategies.

The liveability of the calmed area constitutes the third dimension of traffic-calming impact that was evaluated in this study. While the public health and behavioural implications of traffic calming have been reasonably well investigated in the past, the overall liveability of the calmed area has not been explored to any significant extent. It should be acknowledged that the liveability of an area is affected by multifaceted urban planning aspects, and as such, the direct impact of traffic-calming measures cannot be easily disentangled from other built and physical environment characteristics. Despite these complexities, we identified key components of liveability that may be associated with traffic calming, including the accessibility and comfort of public spaces, the enhancement of social capital, and the increased environmental attractiveness of the calmed area. The reviewed studies showed that traffic-calming measures have the capacity to significantly enhance the accessibility and comfort of public spaces, particularly for pedestrians [19]. Reduced traffic volume and slower speeds create a safer environment, encouraging pedestrians to use public spaces more freely. Such increased utilisation of public spaces enhances the well-being and liveability of residents, making neighbourhoods more walkable, accessible, and vibrant [22,29]. Furthermore, reclaiming public spaces from motorised vehicles fosters greater social interaction among residents. In this context, traffic-calming measures encourage outdoor activities, increasing opportunities for social engagement and strengthening community bonds [37,43]. This enhanced social activity contributes to a greater sense of security and community belonging. However, further research is needed to understand the specific mechanisms through which traffic-calming influences social capital, and particularly which types of measures, and under what conditions, best foster a more inclusive and socially engaging environment. Also, an important consideration for policymakers involves addressing the unintended spillover effects of traffic-calming interventions. These may include the displacement of traffic to adjacent streets, increased congestion or emissions in untreated areas, and potential inequities in how such measures are distributed across neighbourhoods. To mitigate these risks, policy strategies should prioritise network- or city-level planning over isolated interventions, ensuring that traffic is calmed in a coordinated and balanced manner. Additionally, implementing complementary interventions such as modal filters, low-traffic neighbourhoods, and school safety zones can help absorb redirected flows and sustain behavioural change. Equally critical is the need for continuous community engagement and feedback-informed adjustment, as well as the incorporation of equity criteria when selecting areas for intervention, in order to avoid reinforcing spatial or socio-economic inequalities.

The local area without the burden of excessive car traffic seems more attractive to local residents and visitors, as they perceive the reduction of motorised traffic as a means of improving the standard of living and local well-being. Of course, the enhancement of the local environmental attractiveness is not only a matter of the traffic-calming impacts, but it requires additional urban planning interventions (e.g., pedestrianisation of high streets, more green areas, and so on [43]—see also [62] for more details), which operate synergistically with the traffic calming and magnify their liveability impacts in the long term.

4.2. Differences in Implementation Types: Scale and Scope of Interventions

Figure 3 presents a holistic overview of the impacts of different types of traffic-calming measures on three outcome domains: public health, behaviour, and liveability, as drawn from the findings of the systematic review. Both physical and enforcement-based measures show similar distribution patterns, with public health being the most frequently reported outcome (55% in both cases), followed by behaviour (22.5% and 25.6%, respectively)

and liveability (22.5% and 19.4%, respectively). Psychological measures are exclusively associated with public health outcomes (100%), although this result is based on a single case, which limits its generalisability. Notably, when a mix of traffic-calming measures is implemented, i.e., when constituting a more comprehensive intervention, there is a marked shift in outcome distribution. Behavioural outcomes become the most prominent (43.4%), followed by liveability (30.6%), and public health (26%). This suggests that integrated and multifaceted traffic-calming strategies are more likely to produce balanced benefits across multiple dimensions of urban well-being, rather than concentrating their impact on a single dimension of outcomes.

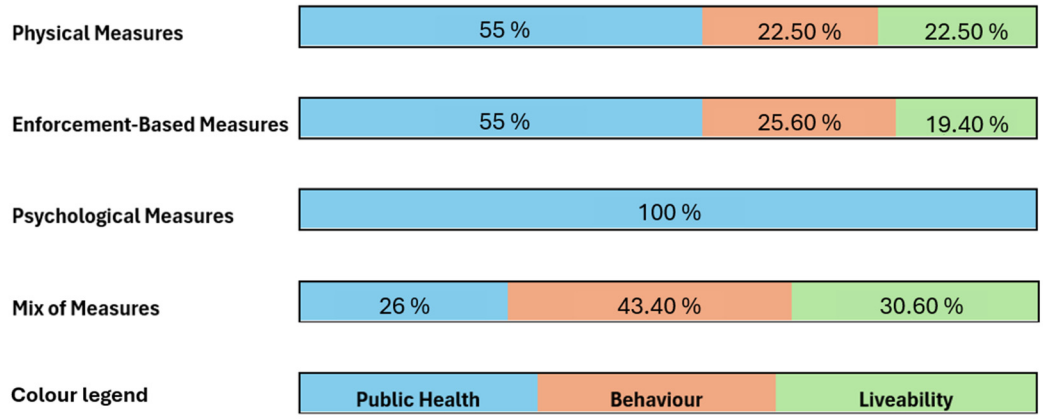


Figure 3. Types of traffic calming and their overall impacts on the three key outcomes.

The studies examined in this review cover a wide range of traffic-calming interventions, varying both in type and scale. Some focus on the impact of a single intervention, while others assess the effects of comprehensive, multi-measure plans. However, the findings suggest that the number and diversity of observed outcomes—including their subcategories—do not necessarily depend on whether the intervention involves a single measure or a combination of measures. Instead, the scale of the intervention area appears to be the key determinant. For example, a citywide intervention implementing 20 mph speed limits in Edinburgh [45] yielded a greater range of outcomes than a comprehensive traffic-calming plan applied to a single neighbourhood in Slovenia [43], despite the latter including several types of interventions. This pattern holds regardless of whether the area is urban or rural. For instance, a mix of traffic-calming measures in a small Swedish community [29] produced more diverse outcomes than a targeted comprehensive intervention in specific neighbourhoods in Singapore [46]. These findings highlight the importance of intervention scale and area-wide coverage in shaping the breadth and depth of traffic-calming impacts.

4.3. Drivers' Responses and Behavioural Adaptation

While the primary focus of this study has been on non-motorised users, understanding drivers' responses to traffic-calming measures is crucial to inform policies that will not exclude this major group of road users and their specific characteristics. From the drivers' perspective, the key implication and difference from the non-motorised users is that such interventions may increase driving anxiety and discourage travel through treated areas. This is supported by findings that show a significant reduction in traffic volume through the treated area after the intervention [43]. Similar impacts indicate disruptions to the usual travel routines and highlight the need for further research to understand in greater depth the cognitive and emotional responses of drivers to these interventions. In spite of the negative perceptions and emotional responses, motorised road users do benefit from the increased level of road safety alongside non-motorised users, thanks to traffic-calming measures.

Furthermore, a limited number of studies [32,34] suggest that social influence plays a significant role in shaping drivers' adaptation to new driving behaviours and habits following the implementation of traffic-calming measures. This finding aligns with the theoretical pathway illustrated in Figure 2 and reinforces the idea that perceptions act as mediators in the realisation of behavioural change. Social influence can affect—to some extent—perceptions, but in conjunction with other dimensions relating either to the intervention itself (e.g., effectiveness, convenience, availability of other options), the user (e.g., personality traits, personal exposure, past experience) or the driving community overall (e.g., cultural factors, community values). The inter-relationship between attitudes and behaviour from the drivers' perspective is quite under-explored, and more comprehensive research is required to understand how traffic calming impacts drivers' perceptions and behaviours and to get a more comprehensive and inclusive picture of the effects on urban mobility and liveability.

4.4. Area of Traffic-Calming Interventions

Another key finding from this analysis is the predominant focus on urban settings in existing research on traffic calming and collision rates. While urban areas have been extensively studied, there is a notable gap in understanding how these measures perform in rural contexts, where different traffic dynamics, road infrastructures, and population densities may influence outcomes. A recent study [48] examined the speed-related effects of an area-wide 20 mph intervention in the largely rural Scottish Borders (UK), highlighting the scarcity of empirical data on rural applications. The study underscores the limited generalisability of urban-centric findings and raises concerns about potential biases in how public health outcomes related to traffic calming are interpreted by local authorities and policymakers. This gap in the literature calls for more balanced research efforts that include rural areas to better assess the contextual effectiveness and adaptability of traffic-calming strategies across diverse geographic settings.

5. Conclusions

5.1. Key Findings

In an overall assessment, the following key findings relating to the impacts of traffic calming can be drawn from this study:

- Apart from reductions in the frequency and severity of road collisions, traffic-calming measures can contribute to community public health through the enhancement of air quality and the lessening of vehicle-related ambient noise.
- Traffic-calming measures can bring forth behavioural changes relating to the mobility choices of road users. The calmed areas foster a more pleasant and safer environment, which, in turn, encourages the uptake of active mobility and the adoption of sustainable mode choices. This shift towards active transportation modes contributes to increased physical activity among residents, which corroborates the interrelated effects between behaviour and public health.
- Traffic-calming measures seem to benefit the liveability of the local area through different mechanisms, but mainly through the improvement and greater accessibility of the public space, the enhancement of the social capital, and through the "beautification" of the overall physical and built environment, which makes it more pleasant and inviting for residents and visitors.
- Local residents may spend more time outdoors due to traffic-calming measures, developing stronger bonds with each other and strengthening the sense of community belonging.

- Despite their proven benefits, traffic-calming measures are not universally perceived as beneficial by all road users, especially drivers, who often report frustration, increased stress, and resistance to altered driving routines. Such negative perceptions may undermine the intended safety and liveability outcomes of traffic-calming interventions.
- In some cases, poorly planned interventions—particularly vertical deflection measures such as speed humps—have been associated with increased noise pollution and user dissatisfaction. Additionally, some studies have reported unintended consequences, such as traffic or speeding displacement to adjacent non-calmed areas, which may compromise the overall effectiveness of the intervention.

5.2. Future Research Agenda

Future research endeavours should prioritise a better understanding of the nuanced impact of traffic calming on urban liveability, especially through the prism of quality of life and the overall well-being of road users in calmed areas. Specifically, every facet of liveability—be it accessibility, social capital, or environmental attractiveness—should be individually examined in order to inform future policies in which traffic calming not only serves as a road safety tool but also as a community well-being intervention. Furthermore, the influence exerted by traffic-calming measures on the attitudes and perceptions of motorised vehicle users remains inadequately explored. In most cases, car drivers tend to perceive the changes introduced by traffic calming—particularly reduced speeds—as negative, often overlooking the fact that these measures enhance their own road safety as well as that of other road users. To this end, it is recommended that future studies differentiate between the perspectives of drivers and passengers, as well as between resident and non-resident drivers [63]; it is likely that the perceptions and experiences of these diverse groups of users may diverge—an important distinction that remains largely unaddressed in the existing literature.

Additionally, while the focus has primarily been on densely built urban environments (e.g., city centres or inner neighbourhoods), it is important to investigate the implications of traffic-calming measures on local economies (e.g., in terms of curbside business activities, property values, and so on). According to the findings of this review, the installation of comprehensive traffic-calming interventions is associated with an increase in walking and local mobility among residents, as more individuals (residents and visitors) tend to move around their neighbourhoods on foot compared to pre-intervention levels. Thus, available research indicates a potential boost to the local economy. Given the evident lack of research on traffic-calming schemes in rural areas, future research should also focus on the impacts in such under-represented regions, which present different mobility challenges compared to urban areas.

Moreover, there exists an urgent need for research on the impact of traffic calming in developing or underdeveloped countries, where the absence of robust road safety infrastructure or established safety strategies induces additional barriers to the effectiveness of traffic calming, especially in terms of public health and liveability. Finally, direct links between traffic-calming measures to changes in car use, road user behaviour [64,65], and the adoption of public transport, micromobility, and shared mobility options (i.e., mode choice) remain limited and underexplored. This points out another possible research gap that needs to be addressed to help design future policies that integrate the aspect of mode choice into broader strategies fostering sustainable and carbon-neutral mobility.

6. Limitations

The current research is subject to several limitations. Firstly, three bibliographic databases were used for the review (Web of Science, Scopus, and Google Scholar), with the

primary focus being on peer-reviewed journal publications. The inclusion of additional databases and alternative types of research outputs (e.g., grey literature, policy evaluations, or reports) could unveil further relevant studies with the potential to strengthen the robustness of the review findings. Secondly, identifying studies that not only examined traffic-calming measures but also incorporated aspects of public perception or opinion proved to be particularly challenging. Additionally, this review did not consider emerging vehicle technologies such as connected and automated vehicles (CAVs), which may alter future traffic dynamics and influence the applicability of traditional traffic-calming strategies [66]. Evaluating the interaction of CAVs with traffic-calming interventions may require a more technologically focused review, drawing on studies that utilise more disaggregated, naturalistic, or observational data [67]. Furthermore, a key criterion for the inclusion of studies in the review was the relevance to aspects of liveability, even if addressed indirectly. This specific criterion, in combination with the aforementioned limitations, contributed to a relatively reduced number of included studies compared to the initial pool identified during the screening process.

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Appendix A

Intervention search terms		Outcomes search terms		Perception search terms
(“choker” OR “zebra crossing” OR “speed limit roundels” OR “crosswalk” OR “high visibility crosswalk” OR "speed lump" OR "speed hump" OR "speed cushion" OR "speed kidney" OR " speed bump" OR “chicane” OR "speed table" OR "raised pedestrian crossing" OR "lane narrowing" OR "historic paving materials" OR "rumble stripes" OR "median raised island" OR “gateway” OR "hardened-centerline treatment" OR "vertical deflection" OR "horizontal deflection" OR "20 mph zones" OR " 30km/hr zones" OR "transition zones" OR “intervention” OR "pedestrian priority zone" OR "speed limits" OR "20 mph speed limit" OR "30 km/hr speed limit" OR "Automated speed control system" OR "speed indicator device" OR “high visibility enforcement” OR “traffic cameras” OR “vehicle activated signs” OR "changed surfacing" OR "street-roadside trees" OR " dragon teeth " OR "3D crossing" OR "curb	And	(“crash” OR "injury severity" OR “safety” OR “accidents” OR “speed” OR “collisions” OR “incident” OR "speed management" OR "speed profile" OR "driver's behaviour" OR "driver's perception" OR “fatalities” OR “congestion” OR “driving behavior” OR “driving behaviour” OR "well-being" OR “liveability” OR "public health" OR "active transport" OR "environmental impact" OR “noise” OR "the built environment" OR "quality of life" OR “accessibility” OR "air quality" OR "pedestrian mobility" OR “pollution” OR "noise disturbance" OR "noise annoyance" OR "traffic noise" OR "travel habits" OR "mode choice" OR "traffic safety culture" OR “active mobility” OR “active travel”)	And	("perceived impact" OR "observed impact" OR "public acceptance" OR "public attitude" OR “assessment” OR “evaluation” OR “effect” OR “influence”)

Figure A1. Search strategy.

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