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Review

Review of City-Wide 30 km/h Speed Limit Benefits in Europe

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Abstract: To date, more and more European cities are systematically working to expand the proportion of their street network with a speed limit of 30 km/h. This paper endeavored to assess the effectiveness of city-wide 30 km/h speed limits in Europe. In an effort to condense research outputs, a quantitative approach along with qualitative assessments were implemented. This study described the changes in safety, environment, energy, traffic, livability, and health before and after the phased implementation of city-wide 30 km/h speed limits. The systematic review was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines. Results from 40 different cities across Europe, including Brussels, Paris, and Zurich, indicated that reductions in speed limits improved road safety by decreasing the likelihood of crash risk and the severity of crashes that do occur. On average, the implementation of 30 km/h speed limits in European cities demonstrated a 23%, 37%, and 38% reduction in road crashes, fatalities, and injuries, respectively. Lower speed limits also yielded environmental benefits, with emissions decreasing on average by 18%, noise pollution levels by 2.5 dB, and fuel consumption by 7%, indicating enhanced fuel efficiency and reduced environmental impact. Encouraging citizens to embrace walking, cycling and utilizing public transit services can further contribute to a safer and environmentally sustainable urban environment.

Keywords: 30 km/h speed limits; road safety; speed limit reduction; cities; implementation modalities

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1. Introduction

The European Union's road safety policy framework for 2021–2030 aims to achieve a 50% reduction in road deaths and serious injuries by 2030, with the ultimate goal of "zero deaths on the roads" by 2050, known as "Vision Zero" [1]. Vision Zero is a comprehensive strategy which aims to completely eliminate all traffic fatalities and serious injuries, and promote healthy, safe, and equitable mobility for all road users. First implemented in Sweden in the 1990s, Vision Zero states that any serious or fatal injuries that occur within the road system are unacceptable. This approach is supported by time-limited targets and performance indicators aiming to reduce fatalities and slight and serious injuries [2].

In order to achieve "Vision Zero" in the European Union (EU), the Safe System Approach is promoted [3]. This Safe System prioritizes safer vehicles, infrastructure, lower speeds, and improved post-collision care. In particular, special emphasis is given to safer vehicles through the implementation of regulations and standards for advanced safety features. Additionally, efforts are directed toward enhancing road infrastructure design and maintenance to minimize the risk of collisions and reduce crash severity. Speed management strategies, including lower speed limits in residential streets and effective enforcement, are also crucial to promote safer driving behavior. Improving emergency response systems and post-collision care facilities is essential for better treatment of crash victims and reducing injury severity. Cross-border cooperation is prioritized to enforce traffic regulations consistently across EU member states, while digitalization of driving licenses enhances license management and enforcement.

The implementation of City 30, which enforces a maximum speed limit of 30 km per hour (km/h), aligns with urban sustainability goals, including those outlined in the Cities Mission aiming for zero climate impact by 2030. It serves as a foundational element for initiatives such as the 'Green Footprint' project. By prioritizing spaces conducive to slow mobility, cycling, and walking, City 30 aims to contribute to sustainable urban development. It seeks to promote a variety of transportation modes, enhance safety for pedestrians and cyclists, and foster community engagement and interaction.

In contemporary cities, ensuring traffic safety remains a top priority, prompting government bodies and policymakers to implement strategies aimed at improving road safety and promoting walking and cycling. One such strategy involves lowering speed limits, particularly in areas with high pedestrian density, as a means to reduce the frequency and severity of traffic crashes. Numerous studies have consistently shown that higher speeds increase the chances of being involved in a crash and the severity of resulting injuries [4,5]. By driving at lower speeds, drivers have more time to react to unexpected events, thereby preventing crashes or lessening their impact. Consequently, the implementation of reduced speed limits in residential areas, city centers, and streets with heavy pedestrian traffic is anticipated to decrease noise levels, promote active modes of transportation, and positively influence urban livability [6–8].

To date, several European cities, including Brussels and Paris, are actively pursuing efforts to systematically increase the portion of their street networks governed by a 30 km/h speed limit, either across the entire city or within designated city regions. Many of these cities have adopted a broad implementation of a 30 km/h speed limit as a standard measure, designating it as the default unless otherwise signposted. The adoption of this approach indicates a broader trend toward prioritizing pedestrian safety and urban livability.

This study aims to critically assess the effectiveness of city-wide 30 km/h speed limits. To achieve this objective, a thorough literature review was implemented and the benefits from 30 km/h speed limits in 40 cities across Europe were provided. This paper described the changes in safety, environment, energy, traffic, and livability, before and after the phased implementation of city-wide 30 km/h speed limits.

This paper is structured as follows: First, the overall concept and the motivation of this study is presented, emphasizing the key principles of Vision Zero and Safe System Approach. In the next chapter, the theoretical background with the benefits of lowering speed limits in cities is given. Then, the methodology of this study is provided. This is followed by the cornerstone chapter of the paper covered by an extensive literature review implemented with respect to the effectiveness of city-wide 30 km/h speed limits measuring road safety, traffic efficiency, environmental impacts, etc., in several European cities. The results of the study are then presented, enabling the emergence of road safety-related conclusions. Finally, the main findings are highlighted and recommendations for implementation modalities are also discussed.

2. Background

Reducing speed limits in cities to appropriate levels, such as 30 km/h, can potentially save lives, prevent road crashes, and reduce injuries among all road users. The improvements in both actual and perceived safety and comfort for road users result in positive outcomes across various societal well-being indicators, including safety, health, energy conservation, environmental preservation, accessibility, equality, and economic prosperity [9,10]. Research and scientific evidence suggest that these benefits have direct or indirect economic implications, often quantifiable [11,12].

The enforcement of speed limits is the most effective measure in order to manage operating speeds [13]. It should be noted that speed enforcement yields optimal results when it is difficult to avoid, when it is continued over a long period of time, and when there is a mix of highly visible and less visible activities. Moreover, it is effective to focus on speed enforcement in situations, roads, and times where speeding is having the most effect on road safety levels. To begin with, speed limits were primarily implemented in

order to reduce the frequency and severity of crashes and decrease the generalized cost associated with road incidents [14]. This countermeasure was introduced with the intention of addressing the fact that up to 30% of casualty crashes occurred in cities.

Moreover, lower speeds can directly benefit the environment through the reduced direct and indirect emissions. Specifically, higher speed limits in urban environments are associated with harsh acceleration and braking [15]. Calmer and slower driving can decrease emission rates of carbon monoxide, volatile organic compounds, and oxides of nitrogen emission rates by up to 17%, 22%, and 48%, respectively, depending on the driver's aggressiveness and the gear engaged [16]. An interesting study conducted by Duong and Lee [17] revealed that vehicle speed contributes to the extent of heavy metal contamination, including lead, cadmium, zinc, and nickel found in road dust.

The implementation of 30 km/h speed limits in cities can yield broader public health benefits beyond just reducing fatalities and serious injuries. These include substantial advantages, such as diminished noise pollution, lower rates of obesity, and increased engagement in active transportation. According to Zijlema et al. [18], utilizing active transport modes improves mental health, while Warburton and Bredin [19] have noted that active transportation is associated with a reduced risk of over 25 chronic diseases and promotes longevity.

Studies have shown that traffic-induced noise is the primary source of noise pollution in cities, accounting for approximately 80% of all communal noise sources. In urban environments where speeds range from 30 to 60 km/h, reducing the speed limit by just 10 km/h can lead to decreased noise levels by up to 40%. Vienneau et al. [20] implemented a comparative risk assessment in Lausanne, Switzerland (i.e., comparing areas with 30 km/h speed limits to a reference scenario without such limits) and results demonstrated that 4700 years of life lost were attributable to road traffic noise. It was also estimated that in the lower speed limit scenario, 1 cardiovascular death, 17 diabetes cases, as well as 72 hospital admissions from cardiovascular disease annually could be prevented [21].

In recent decades, road designs have predominantly prioritized motorized traffic without adequately considering streets as public spaces or ensuring all road users' safety. However, practitioners are increasingly moving away from the idea that there should always be a trade-off between safety and speed. Within the framework proposed by Corben [22], known as "movement and place", both mobility and safety concerns can be addressed simultaneously, rather than treating them as conflicting priorities. By implementing speed limits that are tailored to the specific requirements of a road, considering its function as both a "place" and a pathway for "movement", communities can foster more vibrant and livable environments [23].

Enforcing safe speeds can enhance accessibility and consequently reduce the division caused by roads functioning as barriers within cities. In areas with high levels of motorized traffic and fast-moving vehicles, walking can be discouraged, and social interactions among residents living on opposite sides of the road may be limited. This severance can particularly impact communities in residential areas, potentially impeding children from safely crossing roads to reach school or hindering workers from commuting safely between their residences and nearby workplaces.

Lowering speed limits is often met with resistance due to concerns about potential increases in travel times and traffic congestion. However, research generally indicates that any such impacts range between 3 and 5%, and in some cases, reducing speed limits can even lead to improvements in travel times and congestion levels [24]. Despite fears that lowering speed limits may result in slower travel, studies suggest that the benefits in terms of improved safety and other factors often outweigh any change in travel times. The relevant change is usually lower than most people intuitively assume. This may be due to the fact that in dense urban areas, the proportion of the time that can be driven considerably more than 30 km/h is quite low, especially during the times of day when most car journeys take place.

Interestingly, speed limit reduction can sometimes lead to improvements in travel times by smoothing traffic flow and reducing bottlenecks. From an economic standpoint, optimal speeds are those that minimize costs related to safety, emissions, journey time, and other relevant factors. According to Hosseinlou et al. [25], these optimal speeds often tend to be lower than the existing speed limits, highlighting the potential advantages of lowering speed limits for overall road efficiency and safety.

To date, there is limited scientific evidence with regard to the city-wide 30 km/h speed limit benefits. This forms the motivation of the current research, which aims at assessing the effectiveness of 30 km/h speed limits in Europe in terms of safety, emissions, energy, traffic, livability, and health. Particular emphasis in the current research will be given to highlight the effectiveness of city-wide 30 km/h speed limits and provide valid suggestions that could be an effective strategy for reducing road crashes, fatalities, and injuries. It is crucial to realize that in Europe where big parts of the cities are dense, city-wide 30 km/h speed limits are proven to save thousands of lives. The policy recommendation that would follow from this study is to implement city-wide 30 km/h speed limits, rather than 30 km/h speed limits in restricted areas of a city.

3. Methodology

The current study undertakes a comprehensive evaluation of the effectiveness of 30 km/h speed limits in cities. To achieve this objective, an extensive literature review was conducted, focusing on changes in various parameters such as safety, environment, energy consumption, traffic patterns, livability, and public health before and several months (or 1–2 years) after the phased implementation of city-wide 30 km/h speed limits. Stringent selection criteria were employed to incorporate studies into this review, which involved assessing factors such as publication date, study quality, and relevance, as well as the overall credibility and validity of the publication sources. This methodological approach ensures the inclusion of research findings, allowing for the assessment of the impacts associated with the adoption of lower speed limits in cities.

It should be clearly emphasized that the estimated health benefits associated with the current speed limits, as well as additional benefits that could be obtained by the implementation of additional 30 km/h speed limits, can be indirectly revealed through factors such as noise reduction, decreased number of deaths from cardiovascular disease, decreased hospital admissions from cardiovascular disease, decreased incidence of diabetes, as well as reduced levels of annoyance and sleep disturbance in individuals.

3.1. Literature Search

To critically assess the effectiveness of implementing a 30 km/h speed limit in cities, a systematic search across scientific articles and gray literature sources was conducted using the key terms outlined in Table 1. While numerous studies, articles, and commercial websites explore the benefits of speed limit reductions for road safety, this literature review specifically focused on research aimed at objectively determining the impact of city-wide 30 km/h speed limits across various domains including safety, environment, energy consumption, traffic flow, livability, and public health.

Following the establishment of inclusion criteria, the identified key terms were systematically entered into the relevant databases. The inclusion criteria for selecting relevant studies were as follows:

- The search term should be present in the title, abstract, or keywords of the study.
- Studies should have been published from 1992 onwards.
- Studies should include information related to the 30 km/h speed limit in the title or abstract.
- Sources should prioritize scientific journals over peer-reviewed conference papers, followed by scientific reports, articles, or websites.
- Only studies published in English were considered for inclusion.

These criteria were meticulously applied to ensure the selection of studies meeting stringent quality and relevance standards, thereby facilitating a thorough and credible assessment of the effectiveness of 30 km/h speed limits in urban environments.

Table 1. Search terms and screened and included papers.

Key Search	Review Search Terms	Screened Papers	Included Papers
30 km/h speed limit	"30 km/h" OR "20 mph" OR "30 km/h speed limit" OR "speed limit" OR "speed limit reduction" OR "maximum speed" OR "reduced speed" AND "traffic calming" AND "city-wide" AND "cities" AND "implementation modalities"	589	70

The search process was conducted across various databases, including ScienceDirect, Scopus, ResearchGate, Google Scholar and PubMed. Initially, publications were identified and screened based on their titles, resulting in 589 potential research articles. Subsequently, these publications underwent further assessment through abstract screening to determine their relevance to the study's objectives. The limitation was set to include publications from 1992 onwards, with a focus on peer-reviewed English language scientific journals, conference papers, articles, websites, and scientific reports for inclusion. In order to enhance the comprehensiveness of the search, additional relevant search terms were incorporated. Following a thorough screening process, a total of 70 publications were deemed suitable for inclusion in the review. The literature predominantly focused on the topic of 30 km/h speed limits, providing a robust foundation for the critical review and assessment of their effectiveness in urban settings.

Regarding the issue of potential sources of bias, seasonal variations may impact traffic patterns and safety outcomes, potentially complicating the interpretation of the results. To address this concern, a comprehensive analysis that accounted for seasonal trends was conducted by comparing safety outcomes during the post-implementation period to historical data from the same time period in previous years (if available). An attempt was made to include comparisons over long periods of time. However, in many cases, no data were available in scientific papers or articles. As a result, comparisons with several months later were included in the analysis in order to provide an overall depiction of the findings for European cities.

3.2. The PRISMA Procedure

The review conducted in March 2024 adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines to ensure the systematic identification of relevant research articles [26]. Recently updated to incorporate advancements in both conceptual and practical methodologies for selecting, identifying, assessing, and synthesizing studies [27], this review aimed to provide a comprehensive analysis of the effectiveness of 30 km/h speed limits in cities. The initial search was conducted in March 2023, with all databases accessed for the last time in May 2024.

Regarding the PRISMA framework, it serves as a valuable guideline for transparently reporting systematic reviews and meta-analyses. It aids in the identification of relevant studies by facilitating a structured approach to literature search, screening, and selection based on predefined criteria. PRISMA ensures that the review process is conducted rigorously and transparently, thus enhancing the credibility and reproducibility of the findings.

As for assessing study quality, this approach involved a comprehensive evaluation of various methodological aspects to ensure the trustworthiness and reliability of the included studies. This assessment typically encompasses factors such as study design, sample size, data collection methods, and risk of bias. Validated tools and specific criteria to the study type were also employed in order to systematically appraise the strengths and limitations

of each article. Potential bias, such as the COVID-19 pandemic, short-term effect of a speed reduction, or demand changes were also highlighted.

Moreover, it is crucial to acknowledge the inherent complexity of evaluating study quality, especially given the diverse nature of research methodologies and contexts. Therefore, the proposed assessment incorporates a nuanced interpretation of findings, taking into account the overall body of evidence and the consistency across studies. Particular emphasis was given to prioritize transparency in reporting the assessment criteria and decisions, enabling readers to critically appraise the evidence and draw informed conclusions.

Figure 1 provides an overview of the PRISMA flowchart and the search strategy followed.

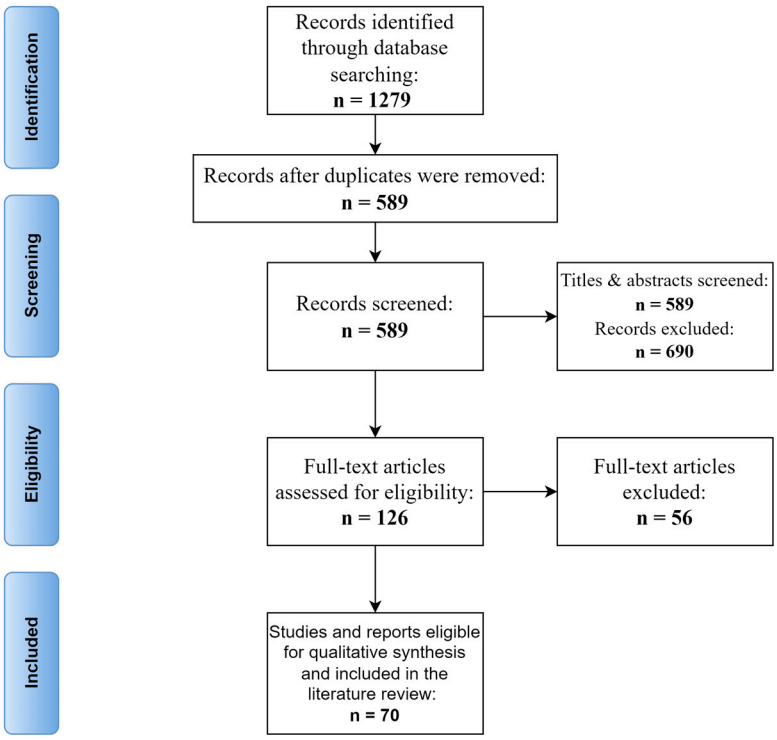


Figure 1. PRISMA flowchart of the systematic literature review.

The search yielded a total of 1279 papers, of which 589 were identified as duplicates. Two reviewers independently screened all papers using a general inclusion/exclusion assessment, following a methodology similar to that of Hawker et al. [28]. A total of 126 articles were selected for full-text review, comprising full papers, articles, websites, and commercial reports recommended by a subject matter expert. Following the full paper review, an additional 56 articles and reports were excluded for not meeting the inclusion criteria. Ultimately, 70 papers, commercial reports, and websites were included in the final review.

4. Literature Review Findings

Scientific evidence has demonstrated that the introduction of city-wide 30 km/h speed limits has resulted in saving more than 37% of lives, alongside positive impacts on the environment, energy consumption, and public health through reduced fuel consumption and increased walking and cycling. Currently, numerous cities worldwide have begun implementing 30 km/h speed limits in substantial portions of their urban areas. Below, a detailed description of the effectiveness of the 30 km/h speed limit in various cities is provided, focusing on safety, emissions, noise, energy usage, traffic flow, livability, and public health. It is worth noting that only cities with populations exceeding 200,000 were considered in this study. Lastly, it should be mentioned that for the majority of cities

examined, data collected came from speed measurements carried out by LIDAR cameras outside the radar zones to avoid the bias of slowdowns dictated by fear of the police.

Previous research on the effectiveness of city-wide 30 km/h speed limits in Europe is limited and lacks some important aspects. Thus, this study addresses a gap in the state-of-the-art literature by assessing the impact of reducing speed limits, focusing on the case of several European cities. The evaluation of 30 km/h speed limits on a city-wide and urban environment level is a novel undertaking. The present work presents a complete framework to evaluate the benefits of reducing default speed limits, which can be adopted by other cities worldwide. The conclusions drawn from this research could contribute to a more comprehensive understanding of the effectiveness of speed limit reductions. These findings may have an impact on future policies and initiatives, promoting safer roads for all users worldwide.

4.1. Safety

First of all, it is worth highlighting that due to the COVID-19 pandemic, 2020 was not a typical year in terms of mobility and road safety. The COVID-19 pandemic had an impact on traffic in EU27, with a corresponding reduction in road crashes, fatalities, and injuries following the introduction of lockdown measures. As a result, for those cities which have implemented speed limit reductions in 2020, part of the exposure reduction can be attributed to the introduction of 30 km/h speed limits, but there are also other crucial parameters that might have led to the relevant decrease (e.g., change demands, traffic patterns).

Most cities implemented the changes fairly recently and just before or during the pandemic (most in 2020 and 2021). Consequently, there is no well-documented knowledge about results from all cities, and existing knowledge mainly concerns more immediate effects such as reduced speed, traffic crashes, noise, air pollution, etc. An attempt was made to take the year 2019 as a reference taking into account the confinements and traffic restrictions on the years 2020 and 2021 which make them non-representative years. The assessment was conducted relatively soon after introducing the intervention.

Findings from the literature review revealed that during the COVID-19 pandemic, average speed increased by 6–11% while a 22% increase in the drivers exceeding the speed limit was observed compared to the 2018–2019 average [29]. Thus, the decreased mobility patterns along with the reduced number of traffic volumes led to a reduction in road crashes and fatalities. This is contradictory with the results derived from the implementation of a 30 km/h speed limit for all cities examined in which lower average driving speeds of up to 7% were found. After this measure, drivers reduced their mean speed and drove conservatively and more carefully which led to improvement of road safety, through the reduction in road crashes and fatalities. Taking the abovementioned arguments into consideration, the study was based on only a few cases (18 out of 40), which in return indicated good results, in which the effect of COVID-19 was not taken into account.

However, it is important to emphasize that it is still too early to document long-term consequences and draw definitive conclusions. While trends from other cities suggest that similar results can be expected over time, it is evident that the 30 km/h speed limit represents a crucial step toward creating safer, more livable cities with fewer road crashes, fatalities, and serious injuries. Although it will take more time to measure and verify these outcomes, knowledge from previous studies has generated clear expectations that reduced speed limits, and vehicular speeds on streets will contribute to such results. The consistent findings across diverse cities suggest that the study may indeed be useful for discussions on the implementation of a general speed limit of 30 km/h in cities.

To begin with, in September 2023, Wales, United Kingdom (UK), has instituted an urban speed limit of 30 km/h, reflecting a comprehensive effort to enhance road safety and improve the overall urban environment [30]. This measure was designed to reduce crash risk, create safer streets for pedestrians and cyclists, and promote a more sustainable and community-friendly approach to transportation. However, the effectiveness of the

introduction of 30 km/h speed limit on road safety in Wales has not been examined yet. Starting on 8 December 2023, Amsterdam, The Netherlands, reduced the speed limit on most of its roads (i.e., 80% of Amsterdam's roads) to 30 km/h [31]. With the new speed limit, it is expected to have a 20–30% reduction in serious crashes [32].

In January 2021, Brussels, Belgium, implemented a city-wide 30 km/h speed limit. Under this policy measure, the maximum speed is set at 30 km/h on all roads in the Brussels Capital region, except for major thoroughfares where the speed limit remains at 50 or 70 km/h. Despite being a new initiative for the city, improvements in road safety were observed. In particular, five months after the introduction of the general 30 km/h speed limit, there was an overall 10% reduction in road crashes (i.e., dropping from 708 in the last quarter of 2020 to 635 in the first quarter of 2021). Specifically, during the first quarter of 2021, there were 635 road crashes compared to 814 during the same period in 2020 (i.e., the first quarter of 2020). Findings from Brussels revealed that the reduction in average speed had no impact on journey times. In particular, slightly shorter journey times were observed. Nevertheless, to mitigate any bias stemming from the coronavirus crisis lockdown, these figures were compared with those from the last quarter of 2020, which recorded 708 road crashes [33].

This decrease was also noticeable for serious injuries in Brussels, where a 37% reduction (i.e., from 38 in the fourth quarter of 2020 to 30 in the first quarter of 2021) in serious injuries was identified [34]. It is worth noting that the number of serious injuries was down from 46 in the first quarter of 2020 to 30 in the first quarter of 2021. One year later, a 20% reduction in serious injuries was observed, while fatalities also fell from 13 (2018) and 11 (2020) to 5 in 2021; an overall 55% reduction in the total number of fatalities in 2021 compared to 2020 was found [35]. Nevertheless, it should be clearly mentioned that a large part of this reduction (−55% in the number of fatalities) can be attributed to the introduction of the 30 km/h speed limits, but there are also other crucial parameters that might led to this decrease, such as the COVID-19 pandemic. Interestingly, according to Moore [34], the main reduction was found in crashes with vulnerable road users, such as pedestrians and cyclists.

Similarly, in August 2021, Paris, France, initiated the reduction of speed limits to 30 km/h on 60% of Parisian roads, taking concrete steps to enhance road safety and mitigate noise and air pollution. Several months after the implementation of this measure, a 25% decrease in the number of bodily injuries and a 40% decrease in serious and fatal crashes was achieved [36]. The corresponding percentages are exempt from potential bias relating to the COVID-19 pandemic. Findings from Münster, Germany, where 30 km/h speed limits were introduced in July 2021, revealed that one year after the implementation of the 30 km/h speed limit, there was a 72% decrease in the number of people severely injured in road crashes [37]. In November 2021, Zurich, Switzerland, implemented 30 km/h speed limit restrictions on parts of its street network to reduce noise levels and improve residents' health and quality of life. Following this measure, a 25% reduction in road fatalities was observed. Additionally, the incidence of car–pedestrian crashes was reduced by 16%, and the number of injured pedestrians decreased by 20% [38].

With the aim of encouraging the micromobility in the city of Bologna, Italy, from July 2023, the speed limit dropped to 30 km/h. Three months after the implementation of this measure, road crashes have fallen by 14.5% compared to the same period in 2023 [39]. According to the data provided by local authorities, in the period between 15 January and 14 April 2024, there was a 13.4% decline of crashes with injuries and 17% of crashes without injuries compared to the previous year. It was also revealed that there was a 14.7% drop in pedestrians involved in crashes (i.e., from 102 in 2023 to 87 in 2024).

Moreover, in June 2018, Bilbao, Spain, reduced the speed limit to 30 km/h aiming to improve road safety, public health, and quality of life for residents as well as reduce noise and air pollution. Two years later, in September 2020, 30 km/h speed limits were set for the entire city. Between 2019 and 2020, the city had reduced the number of road crashes by 28% [40]. This decrease was mainly due to the implementation of 30 km/h speed

limits; however, it is unclear if part of this reduction could be attributed to the COVID-19 pandemic. Overall, it is important to point to the evidence from Spain, where the speed limit on the majority of roads was changed from 50 to 30 km/h in 2019. After two years of implementation (2019–2021), Spain has reported a 20% reduction in urban road deaths, with fatalities reduced by 34% for cyclists, 31% for the elderly, and 24% for pedestrians. In order to explain this reduction in road deaths in Spain, it should be mentioned that the 30 km/h speed limit on single-lane streets in each direction came into effect in September 2020.

In 2004, Helsinki, Finland, introduced widespread 30 km/h speed limit restrictions, which were later expanded in 2019. Initially implemented in the city center and certain residential areas, these speed restrictions were eventually extended to encompass almost all streets. Following the implementation of this measure, streets with lower speed limits experienced a 9% decrease in road crashes resulting in personal injury. Moreover, in areas where the speed limit was reduced from 40 to 30 km/h, a 19% decrease in pedestrian injuries and a 34% decrease in vehicle damages were observed. The most important improvement occurred in the city center, where traffic-related injuries dropped by 42% [41]. In 2019, coinciding with the city-wide introduction of the 30 km/h speed limit, there were no pedestrian or cyclist fatalities in road crashes. Luxembourg has also expanded its city-wide 30 km/h speed limit to cover all built-up areas, mirroring Helsinki's initiative, where not a single pedestrian or cyclist was killed in road crashes in 2020 compared to 2021 [42].

In general, close to 200 cities in France have introduced a 30 km/h speed limit so far, including Grenoble, Nantes, and Lille. More specifically, in 2016, Grenoble, France, extended traffic to 30 km/h throughout the country. In 2016 and 2017, 43 of the 49 municipalities in the metropolitan area gradually joined this approach, with 30 km/h becoming the rule, making the metropolis the first major urban area to implement the generalization of 30 km/h. There was a reduction in the number and severity of road crashes, with pedestrians in particular spared from crashes [43]. An intriguing study found that the number of pedestrians killed or injured in Grenoble had decreased by 50% since the city implemented a 30 km/h speed limit [44]. What is more, road crashes seem to be decreasing, in number and severity, and pedestrians were particularly spared from crashes.

Similarly, in March 2022, Lyon, France, implemented city-wide 30 km/h speed limit aiming to improve the well-being and health of its residents. One year later, an initial encouraging assessment was drawn up; crash rates dropped by 22%, while hospitalized injuries decreased by 40% [45]. In addition, Lille, France, was another city which has announced a 30 km/h speed limit from January 2021, aiming to improve road safety and make the city streets quieter to encourage more active modes of transport. On 19 August 2020, the council began dropping the city-center speed limit from 50 to 30 km/h with the aim of turning 88% of Lille's roads into 30 zones, except for main roads. With only 44% of its roads having a 30 km/h speed limit back in October 2019, this was a major step and represented rapid progress. In August 2020, Nantes went into the 30 km/h speed limit in more than 80% of the urban roads, while one year later, Montpellier also started the implementation of 30 km/h zones. New signs have been installed at the entrances to the built-up area, identified by road markings, while zones remaining at 50 km/h were exceptions [46].

In July 2016, Edinburgh, UK, reduced the speed limit on nearly all of its roads (e.g., city center, main streets, and residential roads) from 30 miles per hour (mph) to 20 mph (roughly 30 km/h). One year after the extensive evaluation of 20 mph speed limits, a 38% drop was observed, with 371 fewer crashes compared to the previous year. This decrease included fewer crashes involving cyclists and pedestrians [47]. A breakdown of the casualty figures revealed that one year later, the number of fatalities dropped by 23% (i.e., 11 fewer fatalities compared to the previous year) while the number of serious injuries fell by 33% [48]. In a recent study, Abohassan et al. [49] examined the effectiveness of speed limit reduction in Edmonton. It was revealed that the overall number of collisions and injuries as well as fatalities resulting from collisions decreased by 25% and 31%, respectively.

In addition, in June 2016, London, UK, has implemented 20 mph (30 km/h) zones. The implementation of 20 mph zones resulted in an overall 46% decrease in death and serious

injury crashes, with a 50% reduction specifically for children aged 0–15 inside the zones. Monitoring of the 20 mph schemes by Transport for London [50] revealed reductions in collisions since the implementation of this measure. The number of collisions decreased by 25% (i.e., from 406 to 304), and collisions resulting in death or serious injuries also decreased by 25% (i.e., from 94 to 71), highlighting the substantial impact of reducing speeds across London. Although vulnerable road users (VRUs) remained most at risk on London's roads, collisions involving VRUs decreased by 36% (i.e., from 453 to 290) since the introduction of the 20 mph speed limits. Particularly encouragingly, collisions involving pedestrians decreased by 63%.

In Bristol, UK, the implementation of 20 mph zones has resulted in a 63% reduction in fatalities at the city level [51]. Similarly, in Warrington, there was a reported 43% reduction in serious and slight pedestrian injuries compared to the 18-month period before the experimental period [52]. Furthermore, in Brighton and Hove, 20 mph limits were introduced in the city center in April 2013. In the first year of implementation, traffic speed has dropped on 74% of roads, leading to 327 fewer casualties (−45%), including a 1% reduction in fatal injuries, an 11% decrease in serious injuries, and a 33% drop in slight injuries [53].

In 1992, Graz, Austria, was the first major European city which introduced a general 30 km/h speed limit in all city areas, aiming to improve road safety, air quality, and reduce car reliance. Nowadays, the 30 km/h speed limit applies to nearly 80% of the city's road network, encompassing all residential roads, school zones, and areas adjacent to hospitals. Already in the first two years of the policy, a 12% reduction in the number of road crashes was identified while 20% fewer persons were seriously injured after introducing the reduced speed limits from 50 to 30 km/h [54]. At the same time, road crashes involving pedestrians and motorists also decreased by 17% and 14%, respectively [55]. As there were no other policy changes related to safe transportation during the same time period, the success could be probably attributed to the implementation of 30 km/h speed limits; but of course, there might be other aspects which can affect safety besides policy. Interestingly, the number of crashes began to rise again since 1996, but this was attributed to crashes occurring on higher-level roads where speed limit restrictions did not apply. In areas with 30 km/h limits, the total number of crashes remained constant or even decreased [41].

Scotland's biggest city, Glasgow, introduced 30 km/h speed limits at the end of 2019 in order to create safer streets and make cycling and walking more appealing options for everyday transportation. In Glasgow, there are currently eighty-two 20 mph zones covering 288 km of roads, including the city center. Analysis of the police database revealed a total 31% reduction in the number of casualties within these zones since the implementation of this measure [56]. In Berlin, Germany, the introduction of a 30 km/h speed limit in 2017 has led to a drop in crash rates by around 10% from 2017 to 2020 [57].

Previous research has examined the impact of reducing speed limits from 50 to 30 km/h on actual driving speeds [54,58–62]. Specifically, after the implementation of 30 km/h speed limits in Wales, United Kingdom (UK), average speeds decreased by 12.8% [30]. Similarly, preliminary figures from Brussels, Belgium, indicated a 7% reduction in average speed on streets that adopted the new 30 km/h limit [63]. However, it was noted that this effect increased over time. For the city of Grenoble, in France, a reduction of 4.2 km/h in mean speeds was demonstrated, resulting in an average speed slightly above 30 km/h [64]. Additionally, Hu and Cicchino [7] collected vehicle speed data before and after the implementation of speed limit reductions in Boston and at control sites in Providence, Rhode Island, where speed limits remained unchanged. They observed a decrease in average driving speeds by 0.3%.

It should be noted that while a decrease in driving speeds was revealed, the extent of this change can vary depending on several factors, such as the speeds driven before, the implementation of design alterations like speed bumps, enforcement levels, the presence of children and pedestrians on roads, and public awareness campaigns. Moreover, compliance with reduced speed limits is typically higher when the speed limit has been reduced

in city-wide areas compared to individual streets. Interestingly, a commonly observed phenomenon is the "spill over effect" [58,65], where driving speeds also decrease on streets unaffected by the speed limit reduction. This is attributed to drivers adjusting to a new driving speed, making 50 km/h feel relatively faster after driving at 30 km/h for a period, compared to constantly driving at 50 km/h.

Lastly, it should be clearly mentioned that according to the preliminary results, only positive effects with regards to 30 km/h speed limits and road safety were identified. In particular, for all reports and studies examined, speed limit reductions from 50 km/h to 30 km/h were associated with a decreased number of road crashes, fatalities, and injuries, and no negative impact was observed.

4.2. Environment

As already mentioned, in January 2021, Brussels, Belgium, established a city-wide 30 km/h limit. Five months after the implementation, there was a reduction in traffic noise by 2.5 db. Similarly, the introduction of 30 km/h limits in Paris, France, in August 2021, aimed to enhance air quality and mitigate noise pollution. It was revealed that noise pollution decreased by 3 dB following the implementation of reduced limits. Similarly, in November 2021, Zurich's decision to lower its speed limit was primarily driven by the goal of reducing noise pollution. After implementing this measure, it was found that traffic noise decreased by an average of 1.6 dB during the day and 1.7 dB at night [66].

The implementation of city-wide 30 km/h speed limits has led to reductions in noise levels. For example, in Buxtehude, Germany, there was a reduction of 7 dB [67]. Similarly, in Graz, Austria, noise levels decreased by 1–2 dB, while in Berlin, Germany, a reduction of 3 dB was observed [67]. In Modena, Italy, noise levels decreased by 3–5 dB [68] and in Sweden, low-speed zones resulted in an average noise reduction of 3–4 dB, with a maximum reduction of 7 dB [69]. These findings underscore the impact that implementing city-wide 30 km/h speed limits can have on reducing urban noise pollution, thereby contributing to an improved quality of life for residents. It should be clearly mentioned that the above-mentioned values refer to the average decrease in noise level (expressed in dB) throughout the day. Additionally, where available, separate data on reductions in traffic noise during the day and night were provided.

In order to evaluate the impact of speed limit reduction from 50 to 30 km/h on noise and air pollutant emissions in Münster, Germany, research was conducted and data before and after the introduction of the speed limit were utilized [70]. It was found that speed limit reduction led to a reduction in road traffic noise, both metrologically and mathematically, and the introduction of a 30 km/h speed limit had a positive effect on air pollution by decreased nitrogen dioxide (NO_2). In Edinburgh, UK, the speed limit on nearly all of its roads was reduced from 30 mph to 20 mph. One year later, the areas with the reduced speed limit experienced a reduction in particulate matter (PM) by 8% [62]. A similar pattern was identified in London, where an 8–10% decrease in PM was observed, after the introduction of 20 mph zones.

In January 2017, Berlin, Germany, implemented 30 km/h speed limit to five main roads. Following this measure, improvements in air quality were observed. In particular, nitrogen dioxide and monoxide emissions decreased by up to 29% from 2017 to 2020 in four out of the five cases [41]. Furthermore, in June 2018, Bilbao, Spain, reduced the speed limit to 30 km/h with the aim of reducing noise and air pollution. One year later, the city experienced reductions in air pollution; an 11.4% decrease in NO_2-μm^3, a 17.1% decrease in NO_X-μm^3 and a 19.1% decrease in PM_{10} was identified [40]. Another important finding of the impact assessment in the city of Graz, Austria, was that noise levels and NO_x emissions dropped by 2.5 dB and 25%, respectively, when maximum speeds of 30 km/h were introduced [54].

On the other hand, opponents of 30 km/h speed limits in cities have criticized their efficacy with respect to air pollution (CO_2, NO_x, and particulate matter). Specifically, two assumptions were made: the former refers to the emission levels when a car is driven at

constant speeds (30 km/h versus 50 km/h), while the latter refers to the realistic driving cycle of accelerations and decelerations (i.e., which differ with different speed limits). Regarding the aforementioned assumptions, results from the literature revealed an increase in emissions [71,72]. Based on these findings, 30 km/h speed limits generate more emissions compared to 50 km/h only when the vehicle is at constant speed with no acceleration and deceleration. In fact, a higher speed limit always means more acceleration and deceleration in cities. Moreover, Tang et al. [73] examined the impact of reducing speed limits from 50 to 30 km/h. Their results showed that the emission of NO_x and PM increased due to speed limit reduction. However, the extent of the increase depends on the type of network and the traffic characteristics. Moreover, Gressai et al. [74] provided a more nuanced analysis, arguing that the impact of revealed speed limits on traffic can vary depending on network topology and emphasizing the need for careful planning and analysis before implementing speed limit reductions.

4.3. Energy

Previous studies have shown the effectiveness of 30 km/h speed limits in terms of energy and fuel consumption. Based on the literature, lower speeds lead to lower fuel consumption while smoother traffic flow leads to additional fuel economy, i.e., eco-driving [75]. Similarly, Ahn and Rakha [76] investigated the environmental and energy impacts of traffic calming measures, such as the implementation of 30 km/h speed limits in residential areas. It was revealed that designs that require drivers to maintain a more consistent low speed, rather than rapidly accelerating and decelerating, were not only better for road safety but also for fuel consumption and emissions.

In a survey implemented in the Netherlands by Haworth and Symmons [77], it was found that lowering speed limits and modifying driving style were found to improve fuel economy and other environmental outcomes in addition to improving safety. In particular, results demonstrated that with speed limit reduction, fuel consumption declined by 11%. In addition, Litman [78] attempted to quantify the energy and environmental impact of 30 km/h speed limits. The results indicated that when vehicle speeds reduced speeds from 50 km/h to 30 km/h, a 7% decrease in fuel consumption was identified. Rowland & McLeod [79] revealed that decreasing maximum speed by 20% (i.e., from 50 km/h to 40 km/h), fuel consumption decreased by 3.4%. However, these effects are relatively small and are often offset by a more continuous traffic flow (or less accelerations) and reduced car traffic which may be due to reduced capacity and other modes being more attractive [71].

Nevertheless, it should be noted that there are a few concerns about the positive effect of 30 km/h speed limits on fuel consumption. There are arguments often raised against low-speed zones, that vehicles have less efficient fuel consumption at lower speeds and can also generate more emissions, reducing air quality [80]. For instance, Woolley et al. [81] claimed that fuel consumption may be under lower speed limits, although this result may have been biased to some extent by the specific fuel models available in the study. This may be due to the common understanding that traditionally, motor vehicles were designed to maximize fuel consumption when operating at around 50 km/h. However, cities with such speed limits typically generate patterns of harsh acceleration and braking for intersections, turns, or traffic congestion. Research has found that this type of travel pattern is worse for fuel consumption and emissions than traveling at a slower but more consistent operating speed, which lowers the amount of acceleration and braking between stops.

4.4. Traffic

It should be clarified that traffic congestion is typically measured using various metrics, including travel times and traffic volumes or traffic flow (i.e., delays in traffic). Travel times are often monitored using GPS data, traffic sensors, or video surveillance cameras installed along roadways, while delays in traffic can be assessed by comparing actual travel times to expected travel times under free-flowing conditions.

Reducing speed limits can prompt road users to choose alternative routes or modes of transportation, which, therefore, has a great impact on traffic volumes. To begin with, in July 2016, Edinburgh in the UK adopted a 20 mph speed limit across all residential areas. Nightingale et al. [62] investigated the impact of speed reduction on traffic volume in the city of Edinburgh. To achieve this objective, traffic data collected before and 12 months after the phased implementation of city-wide 20 mph speed limits from 2016 to 2018 were analyzed. Results indicated an overall 5.7% reduction in average speed and a 2.4% reduction in traffic volumes, but with the direction of effect uncertain. Additionally, the decrease in average speeds was consistent across different days of the week and times of the day, except during the night (01:00–06:00 am) when traffic volumes were relatively low, possibly due to higher average speeds during that time period.

It is worth noting that in Brussels, Belgium, with the implementation of 30 km/h speed limits, no alteration in travel times was identified [82]. Indeed, in some cases, there have been traffic improvements thanks to greater traffic fluidity [83]. In a survey conducted in Bilbao, responders who were initially most resistant to the measures, such as traders, delivery drivers, and taxi drivers proved to be happy to improve traffic flow and acknowledge that the lower speed limit did not cause them any problems [43]. At the same time, with the introduction of the generalized limit throughout the city to 30 km/h, a 2% decrease in traffic in Bilbao was also observed. With the introduction of 30 km/h speed limits in Zurich, travel times had lengthened by between 10″ and 30″ seconds per kilometer, a gap that almost disappeared during rush hour [83].

At the same time, in Grenoble, France, there was a reduction in motorized traffic in the city between 2016 and 2018. In particular, there were 9% fewer light vehicles and 20% fewer heavy vehicles after the introduction of 30 km/h speed limits in urban and rural communities in Grenoble's metropolitan area [43].

It is worth noting that travel times were found to increase between 3% and 5% [60]. The aforementioned increases are usually far lower than most people intuitively assume [24]. This may be probably due to the fact that in dense areas, the proportion of the time that can be driven considerably more than 30 km/h is quite low, especially during the times of day at which most vehicle trips take place.

Like other initiatives that restrict car traffic in cities, public support increases substantially during the implementation. This is mostly because people tend to overestimate the negative impacts, such as increased traffic congestion and longer travel times, while underestimating the benefits of smoother traffic flow. Moreover, the positive outcomes often only become noticeable after the measures are in place, which probably makes them more appreciated afterwards.

4.5. Livability

Traveling by car may be discouraged due to the increase in travel time resulting from lower speed limits. Traveling by bicycle and foot became more attractive due to the declined crash risks, which were also observed in Brussels after the speed limit reduction [34]. In addition, Copenhagen, Denmark, implemented a 30 km/h speed limit in the city center from June 2022 to encourage the use of public transport and reduce CO_2 emissions [84]. However, due to the limited time since implementation, the impact of this measure has not yet been examined.

After the introduction of 30 km/h speed limits in Zurich, Switzerland, pedestrians and cyclists were found to be the most satisfied. In addition, many interviewees reported feeling that the roads were safer and less noisy [43]. In Graz, Austria, one of the primary goals of reducing the speed limit from 50 to 30 km/h was to decrease reliance on cars and simultaneously encourage cycling. Results indicated that after the introduction of 30 km/h speed limits, more than 16% of journeys were made by bike [43]. Interestingly, a survey conducted in July 1992 showed that only 30% of residents were in favor of 30 km/h speed limits before their introduction, while just 8 months later, the satisfaction rate had already risen to 52%, reaching 81% in 2002.

Reducing speed limits not only enhances road safety for all users but also facilitates better utilization of public space, promoting soft and active mobility while providing opportunities to reimagine cities. By lowering the speed limit from 50 to 30 km/h, an average of 20 to 50 cm of roadway is freed up, which can be repurposed for various uses such as extending sidewalks, introducing greenery, and creating cycle paths to encourage multimodality and active travel across the French capital. Similarly, Lille became the first city in France with over 500,000 inhabitants to gradually lower its speed limit to 30 km/h almost everywhere, aiming to prioritize pedestrians and reduce the dominance of cars [43]. The main benefit after three years of implementation was a 55% increase in the number of cyclists compared to 2016 figures [43]. After three years of implementation of 30 km/h speed limits in Grenoble, France, active users approved the proposed approach and cyclists' feelings have improved over the duration of the evaluation: 61% of pedestrians and 70% of cyclists are in favor of the new regulations [85].

4.6. Health

With the introduction of 30 km/h speed limits in Bilbao, findings revealed that there were fewer stressed citizens, with less health problems, and therefore, a quieter city was promoted. Cycling trips increased almost sixfold, from 320,000 in 2018 (before the introduction of the measure) to 1,791,000 in 2022 [83].

Calm driving in lower speeds is a means of promoting healthier living for drivers. All road users, especially children and the elderly, are more likely to walk and feel more confident in venturing outside their homes, trying to cross the street. Additionally, the implementation of city-wide 30 km/h speed limits increases opportunities for work and social interaction and reduces health inequalities through improved accessibility for road users with restricted mobility, hearing, vision, or mental health, as well as children, elderly individuals, pedestrians, cyclists, youth, and commuters [86].

Reducing speed limits in cities will provide substantial cost savings and health benefits. Furthermore, Cleland et al. [87] demonstrated that the widespread implementation of 30 km/h speed limits in cities can improve the health of the public (e.g., road safety, active travel) through reduced emissions and increased physical activity related to walking and cycling. At the same time, Cairns et al. [11] revealed that 20 mile per hour speed limits were found to be an effective means of improving public health via reduced road crashes and injuries.

As already mentioned, the improvements resulting from reduced noise are likely noteworthy. Findings from an interesting study conducted by Rossi et al. [21] revealed that noise reduction was far more important for improvements of public health than the number of reduced collisions. This was likely due to reduced stress levels and improved sleep, which, among other factors, had a positive impact on the prevalence of cardiovascular diseases and diabetes. Similarly, the effects of decreased air pollution in cases of less car traffic could prevent a large number of years of life lost [88]. Lastly, Brown et al. [89] indicated that if active travel modes are increased, a substantial health benefit due to more physical activity will be provided. The overall health effects through the large decrease in road crashes in injuries is probably relatively small when compared to the (possible) extents of increased health due to less noise, less air pollution, and more physical activity.

5. Discussion

Setting a speed limit of 30 km/h in areas where people and traffic mix can lead to safer, healthier, greener, and more livable streets. The reduction in speed limits aims to improve road safety by lowering traveling speeds, thereby reducing the risk and severity of crashes. Additionally, the introduction of 30 km/h speed limits can decrease congestion, improve traffic flow, and reduce travel times by minimizing stop/start traffic movements. Calmer driving at lower speeds promotes healthier living for drivers and all road users. Furthermore, implementing 30 km/h speed limits can reduce fuel consumption, emissions, and noise. Smoother traffic flow leads to additional fuel economy, while streets that prioritize

safe walking and cycling can reduce car dependency and harmful vehicle emissions that contribute to climate change. The introduction of 30 km/h speed limits plays a crucial role in reducing air pollution by decreasing carbon dioxide and nitrous oxide emissions from diesel cars, as well as particulate matter emissions from both diesel and petrol cars. Table 2 illustrates the target goals of cities that have reduced their city-wide speed limit from 50 to 30 km/h, along with the frequency of each motivation given by the 40 cities examined.

Table 2. The target goals of cities which have reduced their city-wide speed limit from 50 to 30 km/h.

Target Goals	Cities
Less crashes, fatalities and injuries	Amsterdam, Barcelona, Bilbao, Berlin, Bologna, Brighton, Bristol, Brussels, Den Haag, Dublin, Edinburgh, Florence, Glasgow, Graz, Grenoble, Helsinki, Hove, Leuven, Lille, Ljubljana, London, Lyon, Madrid, Montpellier, Munich, Münster, Paris, Stockholm, Strasbourg, Toulouse, Wales, Warrington, Valencia, Vienna
Less air pollution	Antwerp, Berlin, Copenhagen, Graz, Leuven, Lille, Ljubljana, Madrid, Münster, Paris, Strasbourg
Less noise	Amsterdam, Barcelona, Bilbao, Brussels, Edinburgh, Graz, Grenoble, Leuven, Lille, Lyon, Münster, Paris, Strasbourg, Zürich
Less traffic congestion	Amsterdam, Berlin, Copenhagen, Florence, Lille
More cycling and walking	Amsterdam, Barcelona, Brighton, Bristol, Edinburgh, Florence, Glasgow, Grenoble, Hove, Lille, London, Lyon, Madrid, Munich, Paris, Toulouse, Wales
Increased livability	Amsterdam, Barcelona, Bilbao, Bologna, Brussels, Copenhagen, Edinburgh, Florence, Glasgow, Helsinki, Ljubljana, Lyon, Montpelier, Münster, Paris, Toulouse, Wales, Warrington
More public space	Amsterdam, Brighton, Bristol, Bologna, Glasgow, Grenoble, Lyon, Montpellier, Münster, Paris
Improved health	Bilbao, Barcelona, Wales

The majority of cities (34 out of 40) cited increased traffic safety, leading to fewer road crashes and less severe collisions, as the main goal of reducing speed limits. A great percentage (35%) of cities (14 out of 40) also identified noise reduction as a reason, while only 11 out of 40 cities proposed this measure to address air pollution, as indicated in Table 2. Additionally, improving the usage of active or alternative transport modes was cited by 18 out of 40 cities as a motivation, and improving the quality of public space was mentioned by ten cities. Eighteen cities mentioned increasing livability, enhancing the friendliness of the city, or improving the quality of life. Improved health was only mentioned by Barcelona, Bilbao, and Wales, mainly as a consequence of reduced noise and increased use of active transport modes. Only five cities (i.e., Amsterdam, Berlin, Copenhagen, Florence, Lille) mentioned the reduction of car usage and traffic congestion as a motivation, though not as the main motivation but rather as a welcomed side effect. It is worth noting that improvement of child play or independence, as well as enhancement of social interactions, social cohesion, or social safety, were not mentioned once as immediate motivations.

It is apparent that most of these cities have only reduced the speed limit in the last couple of years. By the time writing of this paper (May 2024), most cities were in western Europe, mostly France, Belgium, and Spain. For each city, an attempt was made to identify the motivations and ambitions. Figure 2 depicts a schematic overview of the most important—defined as being a pioneer or large—cities with 30 km/h speed limits along with their target goals and motivations.

A comprehensive literature review was conducted to identify cities that have either reduced or intend to reduce the speed limit to 30 km/h on the majority of their streets, including main streets in addition to residential or side streets. Subsequently, comparisons were made between conditions before and after the phased implementation of city-wide 30 km/h speed limits. It is important to note that since many of these cities have only recently lowered their speed limit, the impact of implementing 30 km/h limits in several cities has not yet been fully examined.

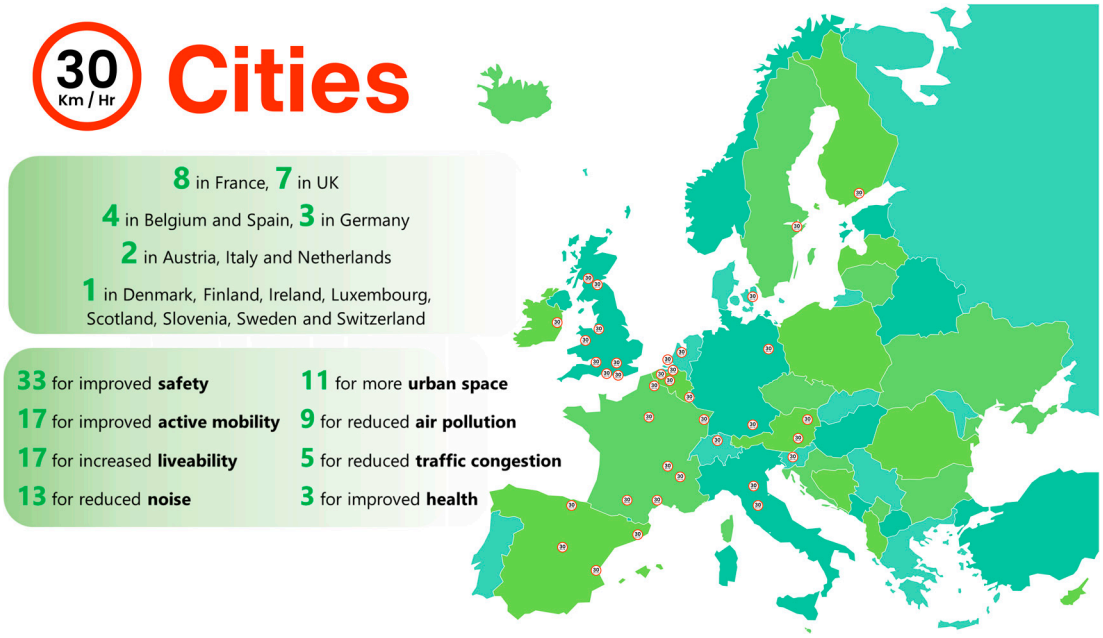


Figure 2. A schematic overview of the cities with 30 km/h speed limits along with their target goals.

Table 3 presents a summary of the effectiveness of city-wide 30 km/h speed limits in terms of safety, emissions, noise, and traffic, while Table A1 in Appendix A provides an overview of the cities which reduced their speed limit to 30 km/h and their motivations to do so by screening scientific papers, reports, and articles. It should be mentioned that the numbering (i.e., from 40 to 1) in Table A1 refers to the total number of cities included in the meta-analysis (i.e., from the oldest to the most recent implementation date started).

Table 3. Summary of the effectiveness of city-wide 30 km/h speed limits.

No	City	Safety			Environment		Traffic
		Crashes	Fatalities	Injuries	CO_2, NO_x, PM	Noise	Congestion
40	Amsterdam						
39	Wales						
38	Bologna	−14.5%					
37	Florence						
36	Copenhagen						
35	Lyon	−22%		−40%			
34	Den Haag						
33	Zurich	−16%	−25%	−20%		−1.7 dB	
32	Toulouse						
31	Vienna						
30	Paris	−40%		−25%		−3 dB	
29	Montpellier						
28	Münster			−72%	↓	↓	
27	Valencia						
26	Leuven						
25	Brussels	−10%	−55%	−37%		−2.5 dB	
24	Nantes						
23	Glasgow		−31%				
22	Antwerp						
21	Barcelona						
20	Lille						
19	Helsinki	−9%		−42%			
18	Madrid						
17	Bilbao	−28%			−19%		−2%

Table 3. *Cont.*

No	City	Safety			Environment		Traffic
		Crashes	Fatalities	Injuries	CO_2, NO_x, PM	Noise	Congestion
16	**Strasbourg**						
15	**Dublin**						
14	**Berlin**	**−10%**			**−29%**	**−3 dB**	
13	**London**	**−46%**	**−25%**	**−25%**	**−10%**		
12	**Grenoble**	**−30%**	**−20%**	**−50%**			**−9%**
11	**Ljubljana**						
10	**Luxembourg**	↓					
9	**Ghent**						
8	**Edinburgh**	**−38%**	**−23%**	**−33%**	**−8%**		**−2.4%**
7	**Bristol**		**−63%**				
6	**Munich**						
5	**Brighton**			**−45%**			
4	**Hove**			**−45%**			
3	**Warrington**			**−43%**			
2	**Stockholm**						
1	**Graz**	**−12%**		**−20%**	**−25%**	**−2.5 dB**	

Gray color indicates that the impact of the implementation of 30 km/h in this city has not been examined yet. The symbol ↓ indicates that the quantitative effect of this measure has not been provided; only qualitative impact is given. The above reductions refer to a comparison period before and after the implementation of 30 km/h speed limits which is not the same among all cities examined.

The range along with the average values of the quantitative effect of city-wide 30 km/h speed limit in terms of safety (i.e., crashes, fatalities, injuries), emissions, noise, fuel consumption, and traffic congestion are presented in Table 4. Notably, there was a decrease in road crashes, with an average reduction of 23%, and a maximum reduction of 46%, as indicated in Table 4. This reduction in crashes translates to a safer urban environment, as evidenced by the corresponding decrease in fatalities and injuries by averages of 37% and 38%, respectively, with even more substantial reductions in certain instances. Additionally, the implementation of lower speed limits resulted in tangible environmental benefits, including an average decrease of 18% in emissions and reductions in noise pollution levels by an average of 2.5 dB. Furthermore, fuel consumption decreased by an average of 7%, indicating improved fuel efficiency and reduced environmental impact. Moreover, the reduction of city-wide speed limits contributed to the alleviation of traffic congestion, with an average reduction of 2%.

Table 4. Range and average values of the quantitative effect of city-wide 30 km/h speed limits.

	Range	Average
Crashes	−[9–46%]	**−23%**
Fatalities	−[23–63%]	**−37%**
Injuries	−[20–72%]	**−38%**
Emissions	−[8–29%]	**−18%**
Noise	−[1.7 dB–3 dB]	**−2.5 dB**
Fuel consumption	−[3.4–11%]	**−7%**
Traffic congestion	+[5% up to −9%]	**−2%**

It should be clearly mentioned that Table 4 contains the range and average values from 18 cities for which there was information available. It should be noted that each of the 40 European cities examined had different sizes and characteristics, different total length of 30 km/h implementation area (e.g., 75% of road network, 65% of urban roads, or the entire city center), different population sizes, and different implementation periods for

which the assessment was made, as presented in Table A1 in Appendix A. Taking all the aforementioned arguments into consideration, it was difficult to interpret the results within the context of population disparities. It is still too early to draw definitive conclusions and it is known from other cities that the trend continues more strongly over time. Thus, a conservative approach was followed by simply presenting the average changes observed.

These findings underscore the multifaceted advantages of lower speed limits, not only in enhancing road safety but also in promoting environmental sustainability and improving overall urban livability. As such, policymakers and urban planners should consider the implementation of reduced speed limits as a comprehensive strategy for creating safer, healthier, and more efficient urban environments.

5.1. Research Gaps

The study encountered several limitations that warrant acknowledgment. Firstly, there was a lack of data to quantitatively assess the effects of speed limit reductions on livability and public health. Given that many of these cities have only recently implemented the speed limit reductions, the impact of the introduction of 30 km/h speed limits in several cities has not yet been thoroughly examined through scientific journals and papers. Importantly, to date, there has been no comprehensive evaluation of the impact of city-wide 30 km/h speed limits on road crashes, fatalities, and serious injuries. By the time of writing of this paper, although the vast priority was to include peer-reviewed journals over peer-reviewed conference papers in order to ensure the quality of this paper, there was no evidence found in the literature; thus, scientific reports, articles, and websites were included in the meta-analysis to support our findings. Also, it should be noted that the majority of reports and articles included in the analysis seems valid as it includes results of 1–2 years of 30 km/h speed limit implementation.

It is important to clarify that the results presented in this study are based on limited and primarily anecdotal evidence gathered from various sources, including websites of organizations and public authorities, as well as detailed reports. There is a lack of comprehensive data from all cities based on published papers in scientific journals. Furthermore, the available information primarily focuses on immediate effects such as reduced speed, road crashes, noise, and pollution.

Secondly, it is worth highlighting that due to the COVID-19 pandemic, 2020 was not a typical year in terms of mobility and road safety. The COVID-19 pandemic had an impact on traffic and road safety, with a reduction in road fatalities per million population following the introduction of lockdown measures. It should be clearly mentioned that a great part of this reduction can be attributed to the introduction of the 30 km/h speed limits, but there are also other crucial parameters that might have led to this decrease, such as the COVID-19 pandemic.

Thirdly, the scientific literature review revealed mixed results concerning fuel consumption, energy usage, and the impact of speed limit reductions. While some studies indicate that fuel consumption and CO_2/NO_x emissions might increase when a car is driven at 30 km/h instead of 50 km/h, other research suggests otherwise. For instance, a study by Cerema [85] found that more CO_2 emissions were generated when traveling at a constant speed of 30 km/h compared to 50 km/h, highlighting the pollution generated during frequent deceleration and acceleration typical in urban driving conditions and at higher speeds. However, these effects were generally minor and often mitigated by factors such as a more continuous traffic flow (resulting in fewer accelerations) and reduced car traffic due to other modes of transport becoming more appealing [71]. The relationship between speed and air quality is complex and influenced by various factors including vehicle type, brake and tire wear, variability and consistency of driving speed, and the nature of the road environment. Studies conducted elsewhere have yet to definitively prove either a positive or negative effect on air quality; driving at a 30 km/h speed limit may cause some emissions to rise slightly while others may decrease.

Moreover, another limitation of the present collision meta-analysis was that only several months and one or two years' worth of post-implementation data was utilized. Even though the key findings and the outcomes were promising and encouraging, the analysis should be interpreted as preliminary until additional years' data become available in order to guarantee a more definitive and thorough evaluation. Thus, additional data collection and evaluation are needed in order to assess these potential effects. The short-term effects of a speed reduction may be enhanced due to novelty and enforcement; however, the long-term effects of posted speed limit reductions could not be further determined.

It should be noted that the research findings highlighted the importance of context-specific analysis when adjusting speed limits, taking into account factors such as local conditions, traffic volume, and road type. Nevertheless, it is important to recognize that the effectiveness of speed limit changes may vary depending on the specific road network, necessitating careful planning and analysis before implementation. In addition, when a speed limit change occurs on a specific road, it is likely to affect traffic patterns and flow in the surrounding road network, potentially leading to changes in collision patterns. Lastly, the impact of reduced speed limits on aspects such as livability, public space usage, social interactions, social cohesion, life satisfaction, sense of belonging, and sense of street ownership remains poorly studied. Also, the exact effects on mental and physical health have not been directly measured in the existing literature. Even though many cities analyzed listed livability, friendliness of the city, quality of life, and significance or usage of public space as key motivations, these aspects have so far been only seldomly investigated. Therefore, as there is a lack of research evaluating 30 km/h speed limit interventions, not all key public health outcomes have been adequately investigated and reported, meaning perceptions cannot be confirmed or refuted [58,90]. Consequently, this may be considered another limitation of the study.

5.2. Suggestions for Further Research

Overall, the study demonstrated that the implementation of the new speed limit had a positive impact on road safety, as evidenced by reductions in speeds and collisions. However, there were areas where drivers did not comply with the speed limit, indicating the necessity for further intervention. The findings underscored the importance of reducing speed limits to enhance road safety and emphasized the ongoing need for monitoring and evaluation of road conditions to inform decision-making effectively. The framework proposed in this study could be adapted for use by other municipalities and jurisdictions seeking to assess the effectiveness of their residential speed limit reductions.

The present work has highlighted several directions for future investigations aiming to gain a deeper understanding of the outcomes associated with the implementation of 30 km/h speed limits in cities. It is important to gather documentation from additional cities that have adopted similar measures, including smaller towns and cities where such speed limits have been in effect for an extended period. Moreover, interviews with academics and politicians, both within the case cities studied and other municipalities that have implemented similar measures, would provide valuable insights into the decision-making processing and administrative implementation of these initiatives.

Future research should also examine the long-term impact of the effectiveness of city-wide 30 km/h speed limits, as the comparison period before and after the implementation of 30 km/h speed limits was not the same. In the future, the quantitative effect of this measure for more and more cities should be included in the analysis. Finally, the exact effect of 30 km/h speed limits on mental and physical health should be taken into consideration. Future studies should aim to assess the effectiveness of implementing 30 km/h speed limits by examining a range of public health outcomes beyond the impact on average speed, road crashes, and casualties. Moreover, researchers should explore and document any unintended consequences to determine their effects on public and mental health, well-being, and social and environmental inequalities. Lastly, more in-depth qualitative research

is required in order to unpack the health equity impacts of the complex transport system and examine behavior change patterns.

In future research, it will be essential to implement rigorous methodological approaches to address potential biases and enhance the validity of findings regarding the impact of the 30 km/h speed limit reduction on road safety. Conducting sensitivity analyses under various traffic scenarios and employing statistical techniques like interrupted time series analysis to mitigate regression to the mean effects will be crucial steps. Additionally, conducting subgroup analyses and sensitivity tests across different demographic groups, road types, and time periods will help ensure the consistency and robustness of the findings. These comprehensive efforts will be vital for strengthening the validity and generalizability of conclusions regarding the effectiveness of the speed limit reduction in improving road safety.

Further studies should also take into account the average values of quantitative effects appropriately weighted by population size to provide a more accurate representation of the overall effects among cities with available data. The size and characteristics of each city should be also considered, allowing readers to interpret the results within the context of population disparities. This transparency will ensure that our conclusions accurately reflect the diversity of urban settings and avoid oversimplification of the data.

6. Conclusions and Recommendations

Speeding stands as the primary cause of road crashes globally, particularly within urban settings where pedestrians, cyclists, and motorcyclists face heightened exposure and vulnerability in the event of a collision. To mitigate this risk, road environments are being designed to reduce vehicle speeds to 30 km/h or lower. This goal is accomplished through the establishment of 30 km/h posted speed limits, bolstered by measures such as speed enforcement, traffic calming strategies, and the provision of pedestrian facilities. These efforts aim to safeguard the well-being of pedestrians, cyclists, and motorcyclists. Concurrently, the adoption of 30 km/h speed limits is gaining momentum, serving as inspiration for other communities and being progressively implemented in a growing number of cities.

This research paper used an observational study aiming to critically assess the effectiveness of city-wide 30 km/h speed limit in Europe. To fulfil this objective, a thorough literature review was conducted and the benefits from 30 km/h speed limits in 40 cities across Europe were highlighted. The work involved a comprehensive speed, collision, emissions, energy, traffic, livability and health assessment of the roads before and after implementing the new speed limit.

It should be noted that bias is an inherent challenge in research and an attempt was made to mitigate its impact by transparently presenting the methods and limitations of this study. In order to ensure that the balance between evidence and opinion was appropriately maintained, several arguments have been included in the paper. It is important to mention that the benefits of 30 km/h speed limits were highlighted in previous research and many studies revealed that speed limit reductions can enhance road safety and urban livability. This topic represents a complex and evolving area of study, and while scientific evidence and historical examinations may have been limited, a comprehensive exploration of both the negative and positive aspects of this issue was conducted.

The discussion and introduction of 30 km/h speed limits often encounter strong opposition and entrenched resistance, while the voices of supporters tend to be relatively muted and ineffective. It is evident that many people believe that 30 km/h speed limit is pretty low for a standard. In particular, opponents of the 30 km/h speed limit in cities argued that it would prolong travel times, diminishing overall commuting and transport efficiency. Many contend that vehicles are not optimized for optimal performance at such speeds, resulting in heightened fuel consumption and environmental pollution. Skepticism surrounds the actual environmental benefits, with suggestions that slower speeds might paradoxically increase emissions. Doubts persist regarding safety improvements, as some

attribute the issue more to driver behavior than speed itself. Concerns also arise about potential traffic congestion and subsequent crashes. Additionally, there's apprehension that lower speed limits would inconvenience car usage, integral to many lifestyles, and resistance to altering established driving norms and habits further underpins opposition. For instance, when the implementation of 30 km/h speed limit put into effect in Bologna, residents expressed frustration at this new measure. A procession of cars brought traffic to a halt on the day this measure came into force, while taxi drivers threatened to raise their fares in order to compensate for having to drive more slowly.

However, all the above-mentioned arguments regarding the city-wide 30 km/h speed limit might be questionable only for passenger car traffic for the parts of the cities which are not densely populated and without real presence of pedestrians and cyclists. In fact, claims that 30 km/h speed limit leads to increased traffic congestion and higher congestion costs is a myth, unsupported by evidence. In urban centers, traffic flows most smoothly at speeds of 20–30 km/h. Despite shorter following distances, this speed range facilitates the entry of traffic from side streets, ensuring continuous flow. Examination of traffic patterns in Switzerland revealed that 30 km/h allowed the road system to accommodate more cars efficiently, resulting in faster overall travel times. This advantage is particularly significant in a time-sensitive world. Moreover, lower speeds lead to improved driving behavior, reducing environmental issues. Enforcing a general city-wide 30 km/h speed limit is more cost-effective than introducing it gradually. While there are initial expenses, such as adjusting traffic signals, these are outweighed by the broader costs associated with higher speeds, making it an investment in public health. Society's initial expenditures will be recouped within a few years through substantial annual savings in reduced health expenses. For example, Switzerland estimated annual savings of 180 to 200 million Swiss Francs from implementing such measures.

Consequently, politicians and Authorities may exhibit hesitancy in implementing such measures. Thus, the implementation of a city-wide 30 km/h speed limit requires careful planning and consideration of various modalities. Establishing a legal framework is crucial for implementing a city-wide speed limit. This involves reviewing and updating existing traffic laws and regulations to reflect the new speed limit requirements. Coordination with local transportation departments, city councils and law enforcement agencies is also required.

In order to successfully implement 30 km/h speed limits in cities, it is essential to launch public awareness campaigns that emphasize the safety benefits associated with the reduced speed limit and elucidate the rationale behind its implementation, with the overarching goal of gaining public support. Efforts should extend beyond citizens to include politicians, fostering a collective understanding and endorsement of large-scale interventions for improved road safety. This comprehensive approach involves the launch of public awareness initiatives through diverse channels, including media campaigns, strategically placed road signage, informational brochures and community outreach programs. By employing a multifaceted communication strategy, these campaigns aim not only to inform but also to actively engage and unite society in advocating for the adoption of a 30 km/h speed limit, creating a safer and more sustainable urban environment.

Simultaneously, promoting Public Transport and active mobility options is crucial for reducing reliance on private vehicles. Encouraging citizens to embrace walking, cycling and utilizing public transit services can contribute to a safer and more sustainable urban environment. Investing in the improvement of public transit services, expanding cycling infrastructure, and establishing pedestrian-friendly zones will not only make these alternative modes of transportation more appealing but also align with broader initiatives aimed at addressing environmental issues and reducing traffic congestion. In addition, implementing traffic-calming measures is another vital component of creating safer road environments. Modifications to road infrastructure, including the installation of speed bumps, raised crosswalks, traffic circles, and narrower lanes, can reduce vehicular speed, thereby enhancing safety for pedestrians and cyclists.

The integration of Intelligent Transportation Systems (ITS) could also play a pivotal role in enhancing road safety and traffic management. By synchronizing traffic signals with actual traffic flow, congestion can be minimized, promoting a smoother and more efficient transportation network. At the same time, monitoring and evaluation are essential components of any successful transportation initiative. By systematically collecting data on vehicle speeds, traffic volumes, crash statistics, and public feedback, stakeholders can gauge the effectiveness of implemented measures. This data-driven approach enables informed decision-making, allowing for necessary adjustments and continuous improvements over time.

Lastly, it should be noted that collaboration with law enforcement agencies is crucial for the enforcement of speed limits and the overall success of mobility and safety policies. Promoting cooperation between stakeholders at various government levels facilitates the implementation of sustainable policies. Law enforcement officers play a key role in ensuring compliance with the speed limit, and their active involvement can be bolstered through education and training programs. These programs should emphasize the significance of the new speed limit and emphasize the heightened presence of traffic patrols. By fostering understanding and collaboration between the community, government, and law enforcement, a comprehensive approach to intelligent transportation and road safety can be realized.

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Appendix A

Table A1. The target goals of cities which have reduced their city-wide speed limit to 30 km/h.

No	Implementation Started	City	Country	Population	Area with 30 km/h	Target Goals	Sources
40	December 2023	Amsterdam	The Netherlands	1,165,898	80% of the roads will have 30 km/h	Safety, less noise, less car usage, more public space for other usages, increased livability	[31,32]
39	September 2023	Wales	United Kingdom	3,190,000	Wales adopts default 20 mph speed limit	Safety, more active mobility, increased livability, increased mental and physical health	[30]
38	July 2023	Bologna	Italy	826,471	90% of the perimeter of the most densely populated part of the city	Safety, zero deaths on the roads, promoting sustainable mobility, increasing the quality and usability of the environment and public space	[39,91]
37	November 2022	Florence	Italy	710	5 central roads	Safety (reducing crashes and the number of fatalities), returning public space to pedestrians, reducing traffic congestion	[92]
36	June 2022	Copenhagen	Denmark	1,381,000	In the city center	Encourage public transport use, reduce CO_2 emissions	[84]
35	March 2022	Lyon	France	1,747,575	84% of roads	Safety, less noise, calming traffic, public space for other usages, more active mobility, friendlier streets	[45,93]
34	December 2021	Den Haag	The Netherlands	709	65% of urban roads with 30 km/h	Safety	[32]
33	December 2021	Zurich	Switzerland	1,419,621	Implementation on 40 km of roads	Noise reduction according to legal requirements	[38,41,43,66]

Table A1. *Cont.*

No	Implementation Started	City	Country	Population	Area with 30 km/h	Target Goals	Sources
32	November 2021	Toulouse	France	1,049,246	80% of the Ville Rose road network	Safety, more room for bikes, more active mobility, increased livability	[94]
31	September 2021	Vienna	Austria	1,931,593	75% of Vienna's road network, mostly in residential areas	Safety	[95]
30	August 2021	Paris	France	11,142,303	All Paris except on the ring road, the avenues des Maréchaux, and some other avenues	Safety, less noise and air pollution, more space for active mobility, increase quality of public space, encourage walking, cycling, and use of public transport, increased traffic flow	[36,43]
29	August 2021	Montpellier	France	473,206	Some main roads maintain 50 km/h	Safer, more fluid, more peaceful, sharing space, increase in well-being ("bienveillance"), cohabitation of different modes, more attentiveness to city environment	[44]
28	July 2021	Münster	Germany	317,713	263 municipalities	Safety, less noise and air pollution, more public space, improve urban livability and quality of life	[70]
27	May 2021	Valencia	Spain	836,857	All the streets that have only one lane in each direction of movement	In 2021 for all Spanish cities: align with EU/UN safety guidelines, e.g., −50% severe crashes	[43]
26	April 2021	Leuven	Belgium	102,236	Center of Leuven	Safety, air and noise pollution	[96]
25	January 2021	Brussels	Belgium	1,222,000	All roads in the capital with the exception of the major axes	Safety, less noise, make neighborhoods quieter and greener	[33–35,63,82,83]
24	August 2020	Nantes	France	331,439	80% of the city	Safety for pedestrians and cyclists, reducing noise pollution	[46]
23	January 2020	Glasgow	Scotland	1,689,000	Vast majority of city roads	Safety, more space for active mobility	[56]
22	January 2020	Antwerp	Belgium	53,063	The entire city center	Less air pollution	[97]
21	December 2019	Barcelona	Spain	5,658,472	75% of the city's streets	Safety, less noise, more active mobility, physical activity, well-being, livability, reduced effects of climate emergency	[98]
20	August 2019	Lille	France	1,073,395	88% roads	Safety, calmness, evolution of behavior, more soft mobility and public transport, reduced car traffic, less pollution and noise	[43]
19	May 2019	Helsinki	Finland	685,457	2/3 of road network	Safety (Vision Zero—no serious injuries or deaths due to traffic), eco-friendly, focus on children, pedestrians, and cyclists	[41,43]
18	September 2018	Madrid	Spain	6,713,557	80% of the total number of streets and 85% of the total length coverage	Safety, cohabitation of different modes, air quality	[99]
17	June 2018	Bilbao	Spain	353,173	in 2018: 87% set 30 km/h, in September 2020: 100% set 30 km/h	Safety, CO_2 emissions, less noise and thus better health, improved quality of life for residents	[40,43,83,100]
16	February 2017	Strasbourg	France	276,170	Gradually to the whole city	Safety, less noise and emissions	[101]
15	January 2017	Dublin	Ireland	1,255,963	An area between the canals	Safety	[102]
14	January 2017	Berlin	Germany	3,570,750	5 main roads	Safety, air pollution, traffic congestion	[41,57]
13	July 2016	Edinburgh	United Kingdom	548	80% of Edinburgh's streets	Safety, active modes, livability and quality of life	[47,48,62]

Table A1. *Cont.*

No	Implementation Started	City	Country	Population	Area with 30 km/h	Target Goals	Sources
12	June 2016	London	United Kingdom	9,540,576	46% reduction in death and serious injury crashes	Safety, more walking and cycling	[50]
11	January 2016	Grenoble	France	534	80% of the streets	Safety, less noise, reinventing and calming public space, promote active mobility	[43,44,85]
10	September 2015	Ljubljana	Slovenia	286,978	Mix of 30 km/h and pedestrian areas	Safety, air quality, and improve living conditions for citizens	[43]
9	August 2015	Luxembourg	Luxembourg	647,599	Mostly residential areas	Slower traffic and improving quality of life for residents	[42]
8	April 2015	Ghent	Belgium	472	All roads with the exception of the major axes	Slower traffic	[103]
7	2015	Bristol	United Kingdom	467,099	63% city-level reduction in road deaths	Safety, encourage more people to walk and cycle, create more pleasant and shared community space	[51]
6	2011	Munich	Germany	1,566,128	80% of the 2300 kilometers of urban network	Safer for cyclists and pedestrians, promote cycling	[104]
5	2010	Brighton	United Kingdom	277,103	74% of the routes in the city center	Safety, encourage more active travel, provide a calmer space for active forms of travel	[53]
4	2010	Hove	United Kingdom	91,900	74% of the routes in the city center	Safety, minimizing serious casualties, active travel	[53]
3	July 2005	Warrington	United Kingdom	210,829	140 roads in a residential neighborhood	Safety, promote public transport	[52]
2	2004	Stockholm	Sweden	1,656,571	On all residential streets	Safety (Vision Zero—no serious injuries or deaths due to traffic)	[43]
1	September 1992	Graz	Austria	295,424	127.58 km^2 (80% of roads) except priority roads	Safety, less pollution and noise	[41,43,54,55,67–69]

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