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Review

Effectiveness of Mobility and Urban Sustainability Measures in Improving Citizen Health: A Scoping Review

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Abstract: Background: The relationship between mobility and health has multiple dimensions, and the mobility model can be considered a public health intervention. Increasingly, mobility in cities is oriented towards incorporating sustainability criteria; however, there are many very diverse measures that cities carry out in terms of mobility and urban sustainability, and in many cases, these do not receive subsequent evaluation and/or study to analyse their effectiveness or impact. Currently, the literature does not offer any updated review of the measures applied in the different communities and countries. Aim: To carry out a panoramic review of the measures implemented in the last 5 years to analyse which ones report a greater effectiveness and efficiency in health. Results: After applying the exclusion criteria of the study, a total of 16 articles were obtained for evaluation. The measures applied in terms of sustainability are grouped into four subgroups and their subsequent evaluation and possible impact on public health is analysed. Conclusions: The present study found a large heterogeneous variety of sustainability measures in local settings around the world, which seem to reflect positive impacts on population health. However, subsequent evaluation of these measures is inconclusive in most cases. Further research and sharing across macro-communities are needed to establish universal criteria.

Keywords: sustainable mobility; mobility plans; public health

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1. Introduction

In recent decades, profound social, economic, and technological changes have led to a new model of urban mobility. This model, which is tending to be implemented globally, is characterised by an increase in the average distances travelled, changes in the reasons for travel, and changes in the location of productive activities [1].

The distance separating the places where different economic and social activities are carried out has continued to grow in recent decades because of technological and organisational advances. The increase in the speed–distance binomial has allowed the "technological distance" between two points to replace geographical distance, and a large part of the time gained by reducing the working day has been devoted to commuting [2].

On a global scale, we are suffering from atmospheric pollution and global warming due to vehicle emissions, and destruction of natural areas due to the continuous expansion of roads. On a local scale, the configuration of metropolitan areas is shaping an intensive model in the use of private vehicles, cities consume 70% of the planet's natural resources and, in addition, it is expected that within 30 years, more than half of the world's population will be living in urban environments. For these reasons, it is necessary to adapt cities to a sustainable model that allows the coexistence of their inhabitants and their development without aggravating the social and climatic problems in which mankind is immersed [3,4].

As a result, healthy lifestyles, as well as public policies and measures whose social interest is the generation of sustainable urban spaces and mobility have emerged as an important issue in contemporary society, being a fundamental aspect in the public health of the population. In view of this circumstance, governments and institutions promote the revitalization of public spaces, which encourages participation in physical activity and the development of human interrelationships [5]. Thus, an active lifestyle, including walking and cycling, has become a key factor in reducing the impact of chronic diseases, obesity, and/or coronary problems linked to human behaviour, such as those caused by lack of physical exercise [6]. Similarly, when these activities are used as a means of transportation, they promote a less congested urban environment and reduce greenhouse gas emissions, which cause climate change. This has a positive impact on human health [7].

The field of study related to urban mobility and active transportation in cities has emerged as a relevant area of research. The growing interest in caring for the environment has produced a sociological change in broad sectors of society, which is summarised in the implementation of different measures and policies, including polycentric 15-min cities, improved accessibility to public transport, creation of corridors or green lungs, pedestrianisation of streets, bicycle lanes, etc. [8]. Recently, these measures have been distinguished as push or pull measures and policies. This description differentiates between those measures that promote or encourage a sustainable use of the environment, or the improvement of a habit. In addition, these measures are aimed at limiting and/or prohibiting the use of a specific type of resource [9].

However, and despite the wide range of measures carried out in relation to urban and sustainable mobility, empirical evidence on the evaluation and/or measurement of these measures seems to show great deficiencies, due to the lack of guidelines in the measures themselves that allow the necessary evaluation of whether or not they are effective, whether citizens perceive them as useful, or whether they have positive repercussions on the health of the population [7].

Therefore, the aim of this paper is to highlight the information and measurements available on this type of urban and sustainable mobility plan implemented in recent years, with the ultimate goal of providing a panoramic spectrum on the most effective models of urban and sustainable sustainability in terms of transferring public health to the population. By accomplishing this task, the aforementioned gap found in the literature, in terms of guidelines, could be fulfilled, providing useful information to the policymakers, thus allowing a first step in the development of possible universal criteria and/or protocols for action, as support tools for local levels, in the implementation of such measures.

Other reviews have made valuable contributions to this debate in recent years in an attempt to unify a useful knowledge base in this regard; however, the heterogeneity of the measures analysed and of the measurements, as well as the local characteristics of most interventions, are a recurrent obstacle to this task. On the other hand, these studies tend to focus on a very specific type of measure, with the result that there are few studies in the academic literature that allow comparison of different types of measures. For example, Stappers et al. [10] were only interested in studies that analysed the effect of changes in city infrastructure. Nieuwenhuijsen et al. [11] only collected studies that analysed the impact of green spaces on the health of citizens in urban contexts. Another more recent review by Nieuwenhuijsen [12] addressed studies on CO_2 emissions, while the meta-analysis by Atkinson et al. [13] focused on NO_2 emissions.

The rest of the paper is organised as follows: the next section addresses a deep explanation of the methodology. Section 3 describes the main results found. Section 4 is a discussion of the results, and finally, Section 5 consists of a summary of the main conclusions, which works as a guideline for policymakers.

2. Materials and Methods

The scoping review was carried out following the methodology proposed by Arksey and O'Malley [14], which is used as a reference in the field. Overview reviews are part of a distinct group of review models that are characterised by answering broader questions and allow analysis of the evidence through a balance of breadth and depth of topic.

This system is made of six steps of working:

2.1. Identify the Research Question

The particular question selected for this overview review is as follows: What has been the public health impact of sustainable urban mobility measures in recent years?

2.2. Search Strategy: Identify Relevant Studies

The research was performed on databases in the Web of Science during the period 2018 to 2022. Articles published in English, Spanish, French, and Portuguese were included. This search was carried out by two experts in scientific literature searching (DC, CF). The search terms used, and their respective results are listed in Appendix A, according to the taxonomy of each database. This search strategy aims to identify papers published in recent years that address the impact of sustainable urban mobility measures on public health, understood in a broad sense, which includes both direct and indirect measurements of public health impact.

We initially reviewed all references obtained, both empirical studies and non-empirical studies. Python language was used to process the files with the bibliographic records. Duplicates were removed to obtain a preliminary selection of studies.

The screening process was carried out in three stages: First, the titles and abstracts of all articles were reviewed by two authors independently (DC and CF) to determine eligibility. In the second phase, both extensively reviewed each provisionally selected article using an ad hoc review protocol. The final list of articles was sent to an expert (MB), to solicit the opinion on the deletion of articles that are not considered relevant and for the inclusion of new articles. Review by a third reviewer is one of the main keys to the overview review, helping to verify the selection of studies.

The final bibliography was reviewed for thematic analysis and synthesis by all the authors of this manuscript.

2.3. Selection of Studies

This inclusion and exclusion criteria were applied.

This study is focused on papers that fulfil both of the following: to be an empirical analysis and to provide sustainability policies based on previous empirical results. Therefore, systematic reviews are excluded from the focus, as well as papers based on COVID mobility measures and policies that have an impact over limited stakeholders. Likewise, studies supported by experts' opinions are not considered in the final selection among others. Although reviews on the subject were excluded, they were used in the theoretical framework of the study and are thus referenced.

These criteria determine the choice of those studies that can provide universal and applicable measures in different settings and time periods, on which the analysis of effectiveness and efficiency in terms of public health improvement will be carried out.

2.4. Data Extraction and Categorisation

A standardised formula to collect and extract information from each article was designed. This format was piloted, refined through an internal peer review process, and finally applied to all the selected studies by two of the authors (DC and CF). Of these studies, 35% were selected for repeat extraction of information by the other author (MB). This method was used to check the accuracy of the selection of information in the chosen extraction formula. Minor discrepancies were resolved by consensus between the four reviewers. The complete collection process is depicted in Figure 1.

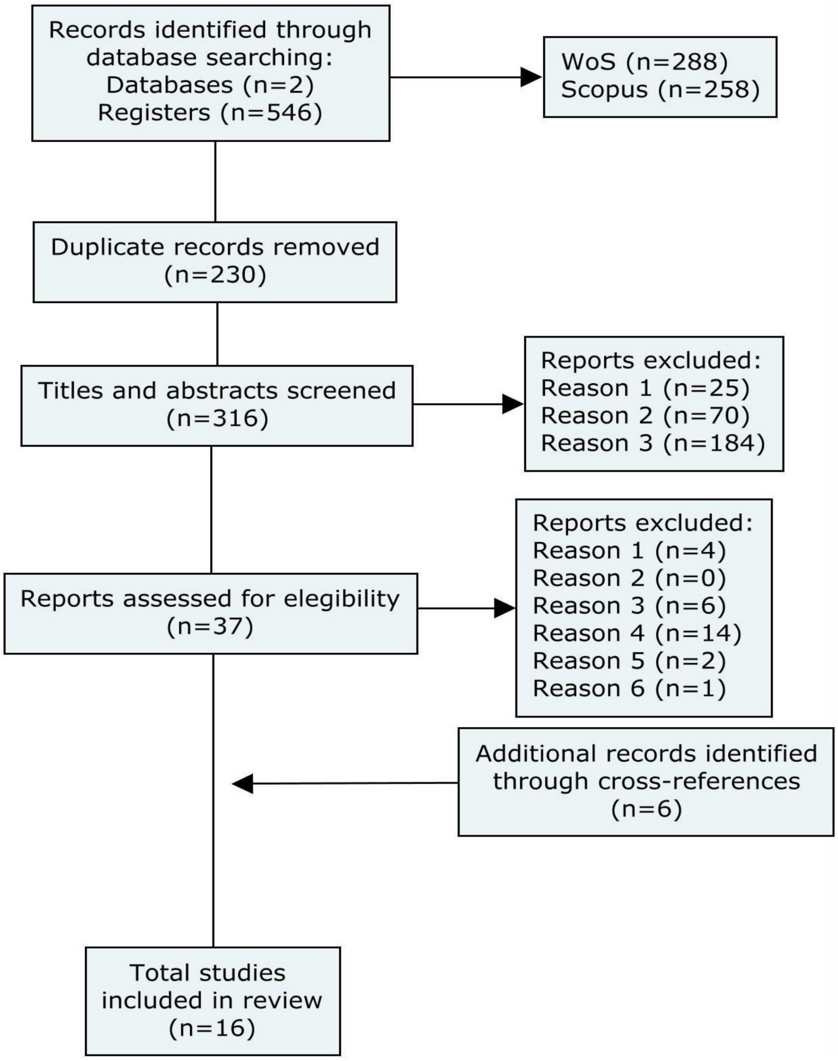

Figure 1. Scoping review search flowchart.

2.5. Quality and Replicability of Studies

To facilitate understanding of the selected studies, given the heterogeneity of their conditions, study population, methodology, and setting, each study was reviewed using the simplified TIDieR criteria (Appendix B).

The resulting 12-item TIDieR checklist (short name, why, what (materials), what (procedure), who provided, how, where, when and how much, adaptation, modifications, how well (planned), how well (actual)) improves the reporting of interventions and makes it easier for authors to structure descriptions of their interventions, for reviewers and editors to evaluate descriptions, and for readers to use the information [15].

2.6. Summary and Reporting Information

The information obtained from each selected article was synthesised as described in Table 1. The variables of analysis selected for the evaluation of the articles were, in order of appearance in the table: authors, year of publication, location of the study, the method of analysis applied, the population or study subjects, the number of participants or sample size, the sustainability and mobility measure analysed, the post-evaluation of the effectiveness of the measure, the analysis subject to the health impact of the measure analysed, and the transferability of the study, and/or the case to other settings or places (Appendix C).

Table 1. Descriptive data of the study variables in the articles.

Variable	Category	Percentage
Impact on health	Yes	81.25
	No	18.75
Transfer	Yes	43.75
	No	56.25
Post Evaluation	Yes	50
	No	50
Measure applied	A	37.5
	B	18.75
	C	31.25
	D	12.5
Push or pull	Push	75 [1]
	Pull	37.5 [1]

[1] Some papers assessed both push and pull measures.

3. Results

3.1. Overall Descriptive Results

A total of 546 articles were initially obtained. After the review process and application of the criteria, 16 articles were finally selected. All were published between 2017–2022, with different locations across the globe. It should also be noted that all selected studies were developed or funded by research centres and/or universities, without finding any study subject to any specific governmental institution. The populations and fields of study present a wide heterogeneity among them, showing quantitative and qualitative studies.

In the analysis applied to extract information on the variables subject to study, the results are summarised as follows. The numerical data can be seen in a synthesised form in Table 1.

The measures carried out are grouped into four different groups, according to the type of measures identified in the selected studies, as follows: measures dedicated to the promotion of cycling (A) (37.5%), interventions dedicated to the improvement of the structure and organisation of public spaces and streets (B) (18.75%), to reductions and/or optimization of the use of motorised vehicles (C) (31.25%), and in plans for mixed measures of urban sustainability (D) (12.5%).

Regarding the results or impact on health, 13 of the 16 articles (81.25%) seemed to indicate that the application and measures can generate a health impact for the population. Three of the articles did not mention the possible health implications of the measures developed.

Regarding transferability, i.e., the possibility of transferring this type of measures to other places or larger spaces, only seven of the articles (43.75%) reflect this possibility.

Regarding the post-implementation evaluation of the measures, which is the subject of this review, half of the articles (50%) made a post-implementation evaluation related to the effectiveness and satisfaction with the use and development of the measure.

Within the definition of push and pull measures (those that seek to incentivize and/or motivate to perform an action, as opposed to prohibiting or limiting an action), we found that the bulk of the measures (75%) were of the push type, seeking to incentivize and/or motivate users to perform specific habits and actions.

3.2. Specific Synthesised Results

The measures that have been grouped in this study as type A, B, C, and D measures, are developed and specified below in a panoramic view, together with the benefits and impacts indicated therein; measures A and C report the highest percentage of use.

Jung et al. [16] analysed the impact of Seoul's Design Street Project on pedestrian satisfaction and traffic on the refurbished streets. This project consisted of a series of improvements to both pedestrian walkways and public spaces, signage, and other relevant street elements, which were implemented between 2007 and 2010. Their results suggest that the improvements to the physical elements of the streets were effective in improving the satisfaction of citizens passing through them but had no effect on the number of people walking on them.

In turn, Marcheschi et al. [17] reported on four car-free street experiments in Malmö and Gothenburg, two Swedish cities, and elaborated an analysis of how citizens perceived the changes that have taken place on the streets. The design of the experiments focused on measures that encourage pedestrian traffic instead of cyclist traffic and took place between 2016 and 2019. They highlight the importance of psychosocial processes when designing and implementing motor vehicle traffic restriction measures, as that they may be a determinant for the acceptability of the measures.

Zhang et al. [18] developed a model to optimise the layout of stations employing bike sharing services. To illustrate their functionality, they employed data collected in Satagaya Ward, Tokyo, via GPS in 2012. The data comprised trajectories of individuals walking, cycling, or driving. The authors used three scenarios to estimate the impact that optimising stations would have on emissions, each with a different ratio of car trips replaced by bicycle trips: 100%, 50%, and 10%. They concluded that their optimization method can potentially reduce emissions by more than 3 thousand tons and improved on forecasts made by other optimization models proposed previously.

Maisel et al. [19] evaluated the perceptions of pedestrians on the implementation of the Complete Street project in the city of Williamsville, New York, between 2018 and 2019. Complete Street projects aimed to improve streets to promote active transportation and public health, among other things. They conducted surveys before (2015) and after (2019) the selected street modifications were made. They found evidence that the changes improved citizen satisfaction but did not necessarily increase physical activity. In fact, they highlight that individuals perceived traffic to run faster, which could be counterproductive.

Egiguren et al. [20] performed a quantitative health impact assessment, with data from 17 countries from the Americas, Europe, Asia, and Africa, to estimate the potential impact on emissions on achieving the targets set by the projections of a previous study (Mason et al., 2015) for 2050. Models were developed for two scenarios: in the first, assuming optimal conditions and 8% of bicycle trips replacing car trips, a reduction of 18,589 premature deaths was estimated; in the second, assuming the same conditions and 100% replacements, the estimate amounts to 205,424 premature deaths in the set of countries analysed.

On the other hand, Otero et al. [21] examined the main bike-sharing systems (with more than 2000 bicycles) located in 12 European cities and evaluated their impact on citizen health using a quantitative health impact assessment. They estimated that these systems avoid, on average, 5 deaths per year, and 73 deaths among all the systems analysed, saving €18 million. Although the use of bicycles also carries some health risks, such as an increase in cyclist fatalities, the results suggest that the potential benefits outweigh the potential harms.

Tao et al. [22] analysed the Dockless Bike-Sharing Service, which is spread across China; this included several improvements to make the use of bikes easier and more attractive, such as the GPS tracking systems and mobile payment among others. The case was studied in Shanghai, the largest DBS market in the world, and focused on comparing the impact of different transport modes. The potential benefits of DBS from emission reduction were assessed as 0.023 and 0.040 CNY/passenger-km, 5.4 min in terms of time savings in journeys of 3 km, and finally, the economic benefit was calculated as 0.085 CNY/passenger-km in high utilisation. The study also evaluated the negative impact of DBS systems in terms of public space occupation; however, this was minor considering the positive effects.

Chatziioannou et al. [23] aimed to assist in the implementation of a comprehensive sustainable mobility and transport plan in Mexico City to improve the quality of life of citizens. To this end, they constructed a global index in which they analysed the sensitivities of each indicator using MICMAC software, which allowed them to organise them according to the quantitative impact they have on urban mobility. The result of their research indicates that the most relevant variable in terms of sustainable mobility was proximity to points of interest followed by block size and shape and public transport coverage. The strength of quantifying the elements allows this study to set a guideline for the implementation of sustainable mobility plans applicable in other environments.

Mueller et al. [24] estimated the health impact of the Superblock Model, implemented in Barcelona, Spain, using a quantitative health impact assessment. This model was composed of numerous measures aimed at reducing motor vehicle traffic in strategic areas of the city. The analysis considered changes in the population's physical activity, air pollution, traffic noise, green spaces, and the urban heat island. A total of 667 premature deaths could be avoided annually after implementing the 503 planned superblocks. Reducing emissions was the main factor affecting the reduction of premature deaths, followed by changes in noise, heat, and green spaces.

Mateu and Sanz [25] examined a comprehensive set of cycling promotion measures implemented in the city of Valencia, Spain, from 2016 to 2020. They used data collected through sensors connected to strategic points of bicycle lanes throughout the city. Their results showed that the city lacks some critical elements, such as bicycle parking areas, integration of bicycles with other transports, and end-of-trip facilities. Despite this, there was an increase in traffic intensity when controlling for seasonality. The authors highlight the success of the city's bike-sharing programme.

Cerutti et al. [26] carried out a study of how the bike-sharing system is perceived in a medium-sized smart Brazilian city, Passo Fundo, and detected the motivations that lead residents to use this means of transport. To do this, they conducted a survey among residents, users and non-users of the system, and the responses were analysed at a descriptive level; more sophisticated techniques, such as the use of Cronbach's alpha factor, varimax rotation for factor analysis, and ANOVA, were used to detect differences between the group of users and non-users. This allowed them to obtain a list of the 10 most relevant variables in the decision to use the bike-sharing system, with the variables related to "Health and environment" having the greatest impact, and to use the interconnections found to guide the development of smart cities and the implementation of sustainable policies.

The work of Billions et al. [27] is the first part of an unfinished research project focused on analysing the key elements of a smart region, specifically those related to mobility. The environment studied was the Western Visayas region in the Philippines, specifically the implementation of "Sustainable Technology-Assisted Route Planning for Region", taking socio-economic data, coverage maps, and inventories of public transport and communication infrastructures built or in progress. As a result, two nuclei of smart cities were detected in the region and the variables with the greatest impact on the future design of the transport system implemented in the region, which will be used in the second part of the research where the effect of smart cities on the development of the region will be evaluated.

In Reche et al. [28], the objective was to study the negative aspects that excessive vehicle use generates at an environmental and health level in the population, as well as to quantify the benefit of carrying out certain mobility interventions in such a way that these results are considered in decision-making and the design of healthier cities. By taking data on pollution levels in 12 European cities and using a long-linear model, the impact on health in the form of increased mortality was obtained. After the application of different measures, a decrease in premature mortality of 1.7% was estimated due to the decrease in exposure to PM2.5 and NO_2 as the main result, which encourages the study of the implementation of more ambitious measures in terms of sustainable mobility.

Cambra et al. [29] performed an ex-ante and ex-post analysis of the Eixo Central project, a programme aimed to improve the walkability conditions in Lisbon. Pedestrian flow data was collected by using the gate method during working days and a survey was conducted in the Eixo Central area, before and after the implementation of the changes, which made the paired t-test a technique suitable with the nature of the study. The main conclusion of this study is the scale of the environmental intervention; larger interventions had a deep impact on population manners regarding walkability, which is not the same for micro-interventions.

The holistic program Madrid City air-quality plan 2020 was analysed by Izquierdo et al. [30], which provided very interesting results regarding the impact of this type of measure on health. By taking data of annual mean concentrations (μg/m^3) of PM2.5, NO_2, and O_3, as well as data on daily mortality from the Regional Statistical Office, the research applied Standardised HIA methods (health impact assessment). The results were very determinant; through a reduction in the annual mean PM2.5 concentration of 0.6 μg/m^3 and 4.0 μg/m^3 for NO_2, the annual number of deaths caused by long-term exposure (95% CI) that could be postponed by the expected air-pollutant concentration reduction was on average 88 for PM2.5 and 519 for NO_2, having the largest impact in the centre of the city.

Barcelona's Superblock Model, focused on reducing vehicles to improve air quality, was analysed by Rodriguez et al. [31]. The methodology used is a multi-scale modelling chain (VML-HERMESv3) and the mesoscale air quality system allowed the evaluation of each measure individually and collectively leading to an interesting result; only when several measures were combined, the effects over emissions were significant. Applying LEZ, TUP, and SPB NOx emission reductions reached 30% and NO_2 emissions 25%. Therefore, the authors recommended the use of this kind of analysis to forecast the impact of each traffic management strategy before the implementation.

4. Discussion

Environmental sustainability has become an essential part of urban performance reporting and planning. Population pressure and proximity to resource limitations, current or anticipated exogenous environmental impacts, and a greater sense of global responsibility have catalysed those planning or governing cities to be guided by studies of environmental sustainability.

This scoping review aims not only to identify and synthesise locally implemented measures for sustainable urban mobility, but also to analyse and study their evaluation and effectiveness in terms of public health. In this sense, the review sheds light on the different measures that are being implemented in different cities around the world, but at the same time, it shows the heterogeneity of these measures, presenting a wide range of urban and sustainable measures. This heterogeneity is even more remarkable in terms of the local areas that analyse the effectiveness of the measure after implementation. In this review, only half of the studies analyse the impacts and results of having implemented the specific measure. Most of the studies (81.25%) seem to indicate that such measures have a positive impact on the health of the population, but only 50% of them are subject to a post evaluation of this impact. This result is in line with the results of previous reviews on similar topics [11].

The information gap persists in the difficulty of performing a health impact analysis, mainly due to the inherent biases of such a study, but also in the difficulty of applying homogeneous measures between local settings, given that these measures are inherently subject to the specific characteristics of both the area of application and the culture and qualities of the population [32].

This scoping review groups the different measures applied in each of the studies into four subgroups: A = measures to promote the use of bicycles; B = interventions to improve streets and public spaces; C = reduction and/or optimization of motorised transport; and D = plans for mixed urban measures, which in turn are grouped into push or pull type measures.

A considerable number of studies regarding the bike sharing system implemented in cities have been found during this research, as possible measures of improvement. Undoubtedly, the interest in urban cycling is increasing, especially over the last 10 years, due to the health advantages it entails. The benefits of bike sharing are flexible mobility, emissions reductions, physical activity benefits, congestion reduction, and fuel use (Shaheen et al., 2010). In addition, it does not produce noise. These positive aspects drive innovation in systems like the dockless bike-sharing system, the core of many studies specifically in China, which has the aim of boosting the use of bicycles by making it easier for citizens.

The second series of measures found in literature are related to interventions to improve streets and public spaces, linked to the concept of walkability. These actions are supposed to be ways of producing environments with lower density, promoting physical activity, extent of street connectivity, increasing the green spaces, and ensuring equality and inclusion among all people. The costs related to the design of the cities are high and they do not seem to have an impact on the traffic on the roads where the improvements are implemented [16,19]; however, they may be justified in terms of improvements in walking conditions. Available evidence suggests that the effect of such interventions is often dependant on the context in which they are delivered and received [10], but the two studies included in this review make no particular reference to this factor.

The main group of pull measures are focused on reducing the use of motorised vehicles since the positive consequences are direct and undeniable; by reducing traffic lanes dedicated to private vehicles and boosting pedestrian and public transport, a decrease in greenhouse gas emissions is achieved. Simultaneously, the health benefits of reducing air pollution have been assessed in several studies; therefore, a relationship between car-free and health impact can be asserted. Somehow, this kind of measure is linked to the former since the outcome of both can be assessed in terms of the improvement in sustainable mobility, and the impact over health is similar [33].

Finally, due to the heterogeneity of cities and metropolitan areas and the huge number of challenges in terms of urban development that should be faced, it is common to find assessments of Integral Plans, which combine different types of measures, with the aim of having a holistic view of the task, satisfying stakeholders from different sectors, including environment, energy, land-use planning, or healthcare. This kind of plan used to involve push and pull measures.

Technological advances in sustainable transportation, energy, and waste management; limiting the use of motorised transport; designing buildings and cities that reduce or improve transportation; mobile applications; creating green spaces; bike-sharing systems; and big data analytics offer opportunities to improve the health of urban populations while reducing their pollution and carbon footprint [34].

However, technological solutions alone are unlikely to solve the persistent environmental, social, and health problems facing 21st century cities around the world. To achieve long-term, sustainable solutions, a concerted and common action is needed by key stakeholders—the government, planners, health professionals, researchers, businesses—as well as individual citizens. To this end, it is necessary to carry out an in-depth analysis of the measures carried out, as well as of the holistic approaches to such measures, to provide, in a comprehensive manner, protocols and support resources that facilitate the implementation at local levels of those measures that are most suited to their characteristics and needs.

The challenges of translating and unifying all these applications into a homogeneous system for generating a sustainable urban environment that effectively improves the public health of the population are complex, requiring a place-based understanding of the potential impacts and opportunities for health improvement that considers the social and cultural context of cities around the world. Most importantly, this requires effective public, political, and business engagement to ensure that scientific findings are translated into viable long-term solutions. Research such as that conducted in the present review can help shed light on the different options and analysis of current measures for sustainable urban mobility.

5. Conclusions

The objective of this study is to make a scoping review of the literature production of the last 5 years on mobility and urban sustainability policies, in order to establish a guide of good manners and to detect the limitations of the analysis already done. The methodology selected allows us to answer wide questions regarding the specific area of analysis, keeping the rigour of systematic reviews but being more flexible. This kind of method requires the researchers to carry out a critical analysis of the available information and it is suitable with the core of the study since there is a wide variety of sustainable urban mobility measures and applications in different local areas. However, most assessments focus on case studies, which makes it difficult to draw conclusions about the effectiveness of the measures.

It has been found that of the studies included in the review, 75% analysed push-type measures, whose objective is to encourage and motivate the population to participate, suggesting that this type of measure is implemented more frequently. On the other hand, about 82% of the measures reflect a positive impact on health, but only 50% of them are subject to a post evaluation of this impact. In addition to this, in a vast majority of cases, several measures from different natures are applied simultaneously. Commonly, it is asserted that the effectiveness of the measures is greater this way. However, there is a lack of methods to evaluate the isolated impact of each initiative to hierarchize and prioritise in case of necessity.

All this considered, further evaluation and analysis of the application, effectiveness, and impact of the measures is needed in order to better adapt and use them in the areas in which they are applied.

This review has some limitations. Firstly, the vast majority of empirical nature studies are specific cases of specific cities. It is common to find the analysis of the same measure in two cities with a difference of several million inhabitants, as well as different climatic conditions, orography, and culture. Obviously, the conclusions obtained in a city should not be applied in another city entirely; however, the challenge faced is to apply them in cities with similar features. To give a general extent and applicability to this kind of studies, as argued in previous works [12], it is recommended to add a comparative analysis where the same methodology was replicated with data from another city of similar characteristics, matching this way the conclusions obtained. Secondly, this review has a smaller number of articles than other reviews conducted in previous periods. This may be because the period chosen for the selection of articles covers the beginning of the SARS-CoV-2 health crisis and its development up to the present day. Articles on the pandemic and possible ways to mitigate its effects through urban planning have dominated much of the literature on sustainable mobility and public health since 2020. These papers are outside the scope of this review. The mobility restrictions put in place by authorities to contain the spread of the virus are a disruptive element that introduces new logics in urban planning and requires its own conceptual framework. While this field of study is interesting, it may have interfered with the development of other work on mobility and public health that did not include an analysis of the pandemic, resulting in a reduced flow of publications on this topic in recent years.

The need to unify criteria and establish protocols for measuring the impact of the measures analysed is evident both in this review and in previous similar work. Future reviews and studies in this area should prioritise the objective of meeting this need to achieve a common framework of analysis that provides a robust knowledge base for public decision-makers.

Despite these limitations, this study opens the path of the succeeding research work, which should take the direction of filling up the aforementioned literature gap by developing an empirical analysis of the specific measures and a ceteris paribus analysis of those measures applied simultaneously, as well as by defining the efficiency in terms of impact health.

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Appendix A

Overall Search Stratergy

Scopus
ABS (health) AND ABS (mobility) AND ABS (public) AND ABS (urban)
WOS
AB = (health) AND AB = (mobility) AND AB = (public) AND AB = (urban)
YEARS
2018–2022
LANGUAGE
English

Appendix B

Table A1. TIDier variables.

Criteria TiDIER	Criteria	Definition
Brief Name	Brief description of the study	Sentence that briefly describes the study
Why	Why the study was conducted	Theory, framework, and objective which frames the conduct of the study.
What How	What the study involved and how it was conducted (materials and procedure) Form of intervention provided	Materials: Physical or automated materials used in the study Procedures: activities, processes, or procedures used in the study
Who Provider	Who conducted the study	Study information providers, including their qualifications, experience, and/or specific training.
Where	Where the study was conducted	Type of location where the study was conducted
When How Much	When and how often the study was conducted	Number of times the intervention analysed was delivered and over what period of time.
Tailoring	What adaptations the study was subject to	If the intervention was adapted or tailored to a specific setting or profile, specify adaptation, why, when, and how
How Well	To what extent the initial plan was conducted	Extent to which what was performed conformed with what was initially hypothesised.

Table A2. TIDieR analysis.

Author	Year	Brief Name	Why	What	Who	Where	When and How Much	Tailoring	How Well
Billones, R.K.C., Guillermo, M.A., Lucas, K.C., Era, M.D., Dadios, E.P., & Fillone, A.M. [27]	2021	Smart Region Mobility Framework	A smart region is a term used to extend the concept of a smart city into both urban and rural settings to promote a sustainable planning approach at the regional level. A direction that must be considered is the adoption of a "Smart Region Mobility Framework" to effectively transform our urban and rural regional transportation networks. This research study focused on the development of the smart region mobility framework for an island region group in the Philippines.	This research study focused on the development of the smart region mobility framework for an island region group in the Philippines.	National research institute	Philippines, Western Visayas regions.	Based on the analysis of 6 provinces, 16 cities, and 114 municipalities included in the study, there are two cities identified as smart city candidates. One of the smart city candidates is designated as the smart city regional centre. The primary data sources include the crowd density in each bus stop, number of passengers inside the bus, the GPS location of the buses and other land-based public transportation vehicles, and real-time ferry and flight schedules in 2020.	The study presented a case study on the limitations of the car sharing service in Sicily (Italy) and these were given special consideration in the analysis.	Traveller Information System (ATIS) was presented and the application and implementation of it can help in regional and urban mobility. Under this smart region framework, when all the transportation service supply and passenger demand data are gathered and analysed suing the EMME 4 transportation planning software, the impact assessment of proposed major transportation infrastructure projects in the region can be developed, especially in addressing the problems of poverty, unemployment, and transportation inequity.
Cambra, P. & Moura, F. [29]	2020	How does walkability change relate to walking behaviour change? Effects of a street improvement in pedestrian volumes and walking experience	Promoting walking has become a policy concern in the public health and transport fields. Street improvement interventions aimed at increasing walking require an assessment of their effectiveness in influencing walking behaviour. There is a current gap in understanding how the magnitude of a change in walkability relates to a change in pedestrian volumes and walking experience.	This study reports a before-after analysis of the effects of a built environment intervention in the walking behaviour of adults in Lisbon, Portugal. The Eixo Central project aimed at improving walking conditions by changing physical factors in three sites—two avenues connected by a plaza. Each site had particular and distinct improvement approaches. We performed a before-after walkability assessment of the intervention area using a validated methodology, a longitudinal analysis of the pedestrian volumes in the intervention sites and control areas, and a quasi-longitudinal survey on the walking experience of residents, workers, and frequent visitors of the area.	University	Lisbon, Portugal.	Walking experience was addressed using a retrospective survey, following a quasi-longitudinal design. This involves asking respondents to recall information on a number of characteristics from a previous point in time as well as for the current time Walkability was assessed using the IAAPE framework proposed by Moura et al. (2017). A walkability score between 0 and 100 is obtained by means of a weight function whose inputs are seven key concerns: connectivity; convenience; comfort; conviviality; conspicuousness; coexistence and commitment.	There were noticeable environmental changes that were not fully captured by the walkability model, relating to design qualities such as imageability, enclosure and human scale and to the provision of amenities and greenery. In addition, replacing traffic lanes by pedestrian space led to fewer nuisances from close traffic.	Higher walkability changes to be associated with a higher increase in pedestrian volumes and to a higher positive influence in walking experience. Conversely, smaller scale walkability changes were associated with a less expressive change in pedestrian volumes and walking experience. The results suggest that the scale of walkability change of environmental interventions is a significant factor in influencing walking behaviour. In this sense, smaller-scale interventions may be effective in improving the walking experience but not as effective in increasing walking activity.
Cerutti, P.S., Martins, R.D., Macke, J., & Sarate, J.A.R. [26]	2019	"Green, but not as green as that": An analysis of a Brazilian bike-sharing system	According to academics and urban planners, the smart city concept favours technological products and solutions over end users and their adherence to a smart city proposal. The smart city concept is also considered in the cities of Latin America, one of the most urbanised and unequal regions of the world. Smart city implementation in such contexts can provide lessons on urban innovation when resources are scarce, and the environments are volatile.	This paper sought to evaluate the perception of bike-sharing users in a smart city and analyse the main motivations for using this system. Questionnaire design	University	Brazil	The research analysed the bike-sharing system of Passo Fundo, a medium-sized city in southern Brazil. Interviews with 526 residents identified three main motivations for using the bike-sharing system: (i) health and the environment, (ii) being social influencer, and (iii) the cyclist lifestyle (2019).	-	The respondents' overall perception revealed their low satisfaction with the bike-sharing system and with the overall conditions for cycling. This finding calls for a better understanding of the planning and management of smart cities in conjunction with citizen's perception and their effects on the city's smartness. The research provides contributions regarding understanding the interconnected aspects of bike-sharing systems in the developing countries context.

Table A2. *Cont.*

Author	Year	Brief Name	Why	What	Who	Where	When and How Much	Tailoring	How Well
Chatziioannou, I., Alvarez-Icaza, L., & Bakogiannis, E. [23]	2020	A structural analysis method for the promotion of Mexico City's integral plan of mobility	Transportation system and its Urban Transportation Infrastructure (UTI) influence an area's economic health and quality of life because they provide the background for the people to perform their everyday activities. Nevertheless, transportation activity generates certain negative externalities like congestion, road accidents, poor air quality that affect the people physically, emotionally, and socially. Consequently, an approach to urban planning is required, which would prioritize sustainable mobility.	An application of the structural analysis method in two steps: first, an identification of the interlinks among the essential urban structure's components for sustainable mobility. Second, the evaluation of the effectiveness of the public policies-strategies that form part of Mexico City's Integral Mobility Plan and organise them in order of importance.	University	Mexico	The global index consists of two parts, the first one is called variable and results from the implementation of the indicators in a CT of Iztapalapa County via a Geographic Information System (GIS). The second part is the constant one and is the outcome of the expert's opinion, resulting from the structural analysis method (2019).	-	The results indicate through the MICMAC software that the most important indicators for sustainable mobility are the proximity to the points of interest, size and form factor of the block, coverage of public transport, total population of the block, land use, block ´s self-sufficiency, sidewalks, road networks of motorized transit, and stations. Consequently, the most important strategy is the "protect" one and more specifically the urban development public policy because it includes the majority of the identified "key" indicators.
Egiguren, J., Nieuwenhuijsen, M.J., & Rojas-Rueda, D. [20]	2021	Premature Mortality of 2050 High Bike Use Scenarios in 17 Countries	Biking plays a significant role in urban mobility and has been suggested as a tool to promote public health, but, no previous studies have estimated the health impacts of global cycling scenarios, either future car-bike shift substitutions.	The aim of the study was to quantify changes in premature mortality of 2050 global biking scenarios in urban populations from 17 countries.	Research Centre	17 countries	Future (2050) biking scenarios in urban populations from 17 countries. The Global High Shift Cycling study forecast future biking scenarios [business as usual and high bike use (HBU)] for years 2030 and 2050, describing future transport patterns, such as trips per person per day, trip length, kilometres travelled by a person, and mode of transport, in all continents around the globe.	Only year 2050 data and results are presented in the main text herein; however, analyses were also performed for the year 2030	Among the urban populations (20–64 y old) of 17 countries, 205,424 annual premature deaths could be prevented if high bike-use scenarios are achieved by 2050 (assuming that 100% of bike trips replace car trips). Global biking policies may provide important mortality benefits in 2050. Current and future bike- vs. car-trip policies should be considered key public health interventions for a healthy urban design.
Izquierdo, R., Dos Santos, S.G., Borge, R., de la Paz, D., Sarigiannis, D., Gotti, A., & Boldo, E. [30]	2020	Health impact assessment by the implementation of Madrid City air-quality plan in 2020	Air pollutant concentrations in many urban areas are still above the legal and recommended limits that are set to protect the citizens' health. Madrid is one of the cities where traffic causes high NO_2 levels. In this context, Madrid City Council launched the Air Quality and Climate Change Plan for the city of Madrid (Plan A), a local strategy approved by the previous government in 2017.	The aim of this study was to conduct a quantitative health impact assessment to evaluate the number of premature deaths that could potentially be prevented by the implementation of Plan A in Madrid in 2020, at both citywide and within-city level.	University	Madrid (Spain)	For exposure assessment, the study estimated PM2.5, NO_2 and O_3 concentration levels for Madrid city in 2012 (baseline air-quality scenario) and 2020 (projected air-quality scenario based on the implementation of Plan A), by means of an Eulerian chemical-transport model with a spatial resolution of 1 km × 1 km and 30 vertical levels. The concentration-response functions proposed by WHO, was used to calculate the number of attributable annual deaths corresponding to all non-accidental causes (ICD-10: A00-R99).	-	Effective implementation of Plan A measures in Madrid city would bring about an appreciable decline in traffic-related air-pollutant concentrations and, in turn, would lead to significant health-related benefits.

Table A2. *Cont.*

Author	Year	Brief Name	Why	What	Who	Where	When and How Much	Tailoring	How Well
Jung, H., Lee, S.Y., Kim, H.S., & Lee, J.S. [16]	2018	Does improving the physical street environment create satisfactory and active streets? Evidence from Seoul's Design Street Project	As the overall interest regarding pedestrian-friendly environments grows, street-improvement projects are continually implemented. These projects aim to encourage walking activities and promote street-based social activities through the improvement of pedestrian environments; however, only a few studies have empirically evaluated the impact of street improvement on pedestrian satisfaction and pedestrian volume.	The research study examines the influence of the Design Street Project of Seoul, Korea, for which sidewalks, public spaces, and the other physical elements of streets were improved.	Research Centre	Seoul, Korea	For a difference-in-difference analysis, the pedestrian-satisfaction levels and the pedestrian volumes of the Design Streets and the matching areas from before and after the implementation of the Design Street Project are compared.	-	Multilevel models indicate that the improvement of the street environment positively influences pedestrian-satisfaction levels but is not effective for increasing the pedestrian volume. The results imply that the physical improvement of street environments can be effective for the elevation of pedestrian-satisfaction levels, as well as quality of life.
Maisel, J.L., Baek, S.R., & Choi, J. [19]	2021	Evaluating users' perceptions of a Main Street corridor: Before and after a Complete Street project	Over 1600 municipalities in the U.S. have adopted Complete Streets (CS) policies to date. For urban planners, the design of CS projects is an opportunity to influence active transportation, transit use, and public health. For users, improved street designs can enhance community mobility and physical activity. To date, there are no practice standards related to CS initiatives, and the implementation of CS projects has not been rigorously studied.	The current study sought to capture the impact of a Complete Streets implementation project in a mid-sized U.S. city.	University	USA	n = 100. A post occupancy evaluation (POE) methodology compared a street corridor before and after it underwent significant street improvements aligned with CS. Convenience samples of pedestrians and bicyclists, both pre- and post-construction, completed a survey either in person using a paper-based survey or online at their convenience.	This study did not address self-selection bias.	Survey results indicated that streetscape users post CS implementation rated the street as significantly more satisfactory than the pre-construction survey participants; frequent walkers reported increased perceived convenience and higher overall satisfaction.
Marcheschi, E., Vogel, N., Larsson, A., Perander, S., & Koglin, T. [17]	2022	Residents' acceptance towards car-free street experiments: Focus on perceived quality of life and neighbourhood attachment	While the twentieth century was dominated by private car usage, shifts towards more sustainable urban mobility, to mitigate environmental damage and increase health benefits, are now taking place. In Scandinavia, several car-free street experiments take form. Specifically, in Sweden, transitory car-free street experiments (i.e., summer streets) are developed with the purpose of creating novel mobility patterns and uses of public spaces that enhance social inclusion and quality of life. Despite Swedish municipalities' monitoring of these interventions, very little is known about which physical parameters (i.e., environmental qualities) and psychosocial processes (i.e., emotional relation with places) affect people's acceptance and place usability during car-free initiatives.	This paper focuses on residents' perception of car-free street experiments. The aim is to identify how acceptance and usability of car-free street experiments might vary depending on the perceived qualities of the physical urban settings and on interceding psychosocial processes such as neighbourhood attachment and perceived quality of life.	University	Sweden	An interdisciplinary methodology of investigation merging knowledge from the field of environmental psychology, landscape architecture, urban transport, and planning was applied on four case studies in Sweden. A convenience sample of residents (N = 1049) participated in the study. Moreover, users of the place, such as pedestrians and bikers, were also included in the study (N = 90) (Malmö N = 39, Gothenburg N = 51). The questionnaires were submitted a first time in June 2019, and then a reminder in August 2019.	Future investigation might want to consider the possibilities to further develop a model (e.g., structural equation modelling), per which the insights derived from this exploratory type of study could be tested in a more confirmatory manner.	Results suggest that psychosocial processes of place attachment and quality of life are relevant to understand the level of acceptance towards car-free streets implementations.

Table A2. *Cont.*

Author	Year	Brief Name	Why	What	Who	Where	When and How Much	Tailoring	How Well
Mateu, G., & Sanz, A. [25]	2021	Public Policies to Promote Sustainable Transports: Lessons from Valencia	Bicycling appears in the literature on urban mobility as a more sustainable transportation mode for future transportation, based on empirical evidence of the potential benefits of bicycling on the environment, society, and health. In this context, public interventions to promote and maintain bicycling as a sustainable practice and its positive effects are salient.	This article reviews different cycling policies with respect to cycling facilities present in the literature and compares them with a case study in Valencia (Spain).	University	Valencia (Spain)	A case study of cycling facilities deployed by Valencia City Council, from 2016 to 2021.	Automatic bike counters cannot discriminate the vehicle type, but neither gender nor other socio-demographic characteristics of users	The consequence of the social demand for cycling facilities accompanied by the constant development of the bike lane network by different local governments has been a steady increase in bicycle users in Valencia throughout the period studied.
Mueller, N., et al. [24]	2020	Changing the urban design of cities for health: The Superblock Model	Car-dependent city planning has resulted in high levels of environmental pollution, sedentary lifestyles, and increased vulnerability to the effects of climate change. The Barcelona Superblock model is an innovative urban and transport planning strategy that aims to reclaim public space for people, reduce motorized transport, promote sustainable mobility and active lifestyles, provide urban greening, and mitigate effects of climate change.	The study carried out a quantitative health impact assessment (HIA) and the estimated the health impacts of implementing Superblock urban model across Barcelona.	University	Barcelona (Spain)	A quantitative health impact assessment (HIA) study for Barcelona residents $\geq$ 20 years (N = 1,301,827) on the projected Superblock area level (N = 503), following the comparative risk assessment methodology. 2020	-	The Barcelona Superblocks were estimated to help reduce harmful environmental exposures (i.e., air pollution, noise, and heat) while simultaneously increase PA levels and access to green space, and thereby provide substantial health benefits. For an equitable distribution of health benefits, the Superblocks should be implemented consistently across the entire city. Similar health benefits are expected for other cities that face similar challenges of environmental pollution, climate change vulnerability, and low PA levels, by adopting the Barcelona Superblock model.
Otero, I., Nieuwenhuijsen, M.J., & Rojas-Rueda, D. [21]	2018	Health impacts of bike sharing systems in Europe	Bike-sharing systems (BSS) have been implemented in several cities around the world as policies to mitigate climate change, reduce traffic congestion, and promote physical activity.	This study aims to assess the health impacts (risks and benefits) of major BSS in Europe.	Research Centre	Europe	The study performed a health impact assessment study to quantify the health risks and benefits of car trips substitution by bikes trips (regular-bikes and/or electric-bikes) from European BSS with >2000 bikes. Four scenarios were created to estimate the annual expected number of deaths. A quantitative model was built using data from transport and health surveys and environmental and traffic safety records. The study population was BSS users between 18 and 64 years old. Twelve BSS were included in the analysis.	The air pollution assessment in this study only considered the health risk associated with the inhalation of PM2.5 during the bike trip. Other changes in air pollution exposure, associated with car-bike substitution at the city level, were not included in this study.	In all scenarios and cities, the health benefits of physical activity outweighed the health risk of traffic fatalities and air pollution. It was estimated that 5.17 (95%CI: 3.11–7.01) annual deaths are avoided in the 12 BSS, with the actual level of car trip substitution, corresponding to an annual saving of 18 million Euros. If all BSS trips replaced car trips, 73.25 deaths could be avoided each year (225 million Euros saving) in the twelve cities.

Table A2. *Cont.*

Author	Year	Brief Name	Why	What	Who	Where	When and How Much	Tailoring	How Well
Reche, C., Tobias, A., & Viana, M. [28]	2022	Vehicular Traffic in Urban Areas: Health Burden and Influence of Sustainable Urban Planning and Mobility	Exposure to air pollutants is of special concern in urban areas because of the dense populations exposed and the diversity of emission sources, with complex chemical patterns. Air pollution is associated with a number of adverse health impacts, including chronic obstructive pulmonary disease (COPD), acute lower respiratory illness (ALRI), cerebrovascular disease (CEV), ischaemic heart disease (IDD), lung cancer (LC) respiratory Tuberculosis, and diabetes mellitus, among others Vehicular traffic is one of the major sources of air pollution in European cities.	This work aims to understand which characteristics of the urban environment could influence mobility-related air pollution, quantify the health impacts of exposure to traffic-derived PM2.5 and NO_2 concentrations, and assess the potential health benefits expected from traffic interventions. The intervention scenarios modelled were designed based on traffic mitigation strategies in the literature and set to ranges of 6–50% in traffic-derived PM2.5 concentrations and of 4–12.5% in NO_2 concentrations.	National research institute	Europe	Targeting a large geographical coverage, 12 European cities from nine countries were comparatively assessed in terms of mean daily traffic volume/area, the number of public transport stops/area, and the percentage of green and outdoor leisure areas, among other urban indicators. Data from 2021.	The absence of uncertainty estimates, which is frequent in receptor modelling studies, was estimated to facilitate comparability between studies due to the comparable sampling methodologies	Practical initiatives to achieve sustainable city design, in terms of transport, include the creation of LEZ, fostering active transport modes, redistribution of public space, promotion of public transport, traffic policies/taxes, and technological improvement/roads management. These measures are known to be able to translate into a reduction of traffic-related air pollutants, which would in turn decrease associated premature mortality.
Rodriguez-Rey, D., Guevara, M., Linares, M.P., Casanovas, J., Armengol, J.M., Benavides, J., . . . & García-Pando, C.P. [31]	2022	To what extent the traffic restriction policies applied in Barcelona city can improve its air quality?	Barcelona city (Spain) is applying a series of traffic restriction measures that aim at renewing and reducing the amount of circulating vehicles to improve air quality. The measures include changes in the built environment to reduce private vehicle space in specific areas through the so-called "superblocks" and tactical urban planning actions, along with the implementation of a city-wide Low Emission Zone (LEZ) that restricts the entry of the most polluting vehicles to the city.	The study quantifies the impact of these measures in the greater area of Barcelona combining a coupled macroscopic traffic and pollutant emission model with a multi-scale air quality model.	National research institute	Barcelona (Spain)	The modelling system allows estimating the effect of different traffic restrictions upon traffic and the associated emissions and air quality levels at a very high resolution (20 m). The measures were evaluated both individually and collectively to assess both their relative and overall impact upon emissions and air quality. The area of study is the greater area of Barcelona, which covers a surface of 101 km^2 and is home to about two million inhabitants. The study is performed from the 9th to the 25th of November of 2017.	The usage of a microscopic tool able to properly estimate traffic flow and vehicle emissions at the studied domain is currently not a viable option due to the data and computational load needed.	It is only when the measures evaluated are combined with optimistic fleet renewal as a result of the LEZ implementation and demand reductions, that relevant global emission reductions in NO_X are obtained. Despite the potential improvements, our simulations suggest that current measures are insufficient to comply with EU air quality standards and that further traffic restriction policies to reduce traffic demand are needed.

Table A2. *Cont.*

Author	Year	Brief Name	Why	What	Who	Where	When and How Much	Tailoring	How Well
Tao, J., & Zhou, Z [22]	2021	Evaluation of Potential Contribution of Dockless Bike-sharing Service to Sustainable and Efficient Urban Mobility in China	China has recently experienced the rapid development of a new generation of bike-sharing service, namely the Dockless Bike-sharing Service (DBS). Though previous studies indicated that bike-sharing is associated with various social, environmental, and economic benefits, unintended adverse outcomes of DBS that constitute public nuisance also have been reported. Thus, it is necessary to assess the DBS effects on urban transport sustainability for strategic decisions on its further developments.	This study is focused on the evaluation of environment-, public-, and individual user-interest related effects of DBS, in terms of efficient resource utilization by sharing, greenhouse gas (GHG) emission reduction, urban transport efficiency enhancement, public space occupation, and individual cost-savings. The assessment models of DBS's resource demand and GHG emission, user transport time and cost, road and roadside parking space demand allocated in the functional unit of transporting one passenger for one kilometre are developed. Economic value models of the reduced resources demand, GHG emissions, transport time, and the occupied public space are then proposed for scaling DBS's overall benefits.	Research centre	Shanghai, China.	A scenario model is proposed to characterise the DBS scheme and the benefits analysis's social-economic backgrounds. The proposed scenario model includes the life cycle models of standard urban transport modes (including DBS), and economic value factor value settings. The quantitative analysis of DBS in Shanghai is presented as a case study for the enrichment of the knowledge pool about DBS in China, as well as insights of DBS's potential contribution to urban transportation sustainability. Two DBS bike life cycle cases—low utilisation" and "high utilisation"—are developed, which have different bike daily turnover rate, useful lifetime, and average journey distance.	-	DBS's evaluation results in Shanghai, the largest DBS market nationwide, showed that DBS's major benefits are journey time saving, followed by travel cost saving. It is also fair to declare DBS as environmentally sustainable, especially considering the emission reduction effects. The value loss from the occupation of public space is minor when compared to the total benefits.
Huang, X., White, M., & Langenheim, N. [35]	2022	Towards an Inclusive Walking Community—A Multi-Criteria Digital Evaluation Approach to Facilitate Accessible Journeys	Half the world's population now lives in cities, and this figure is expected to reach 70% by 2050. To ensure future cities offer equity for multiple age groups, it is important to plan for spatially inclusive features such as pedestrian accessibility. This feature is strongly related to many emerging global challenges regarding health, an ageing population, and an inclusive society. Independent travel to public open spaces, particularly green spaces, is widely considered a key factor that affects human health and well-being and is considered a primary motivation for walking.	This paper introduces a novel open access proximity modelling web application, PedestrianCatch, that simulates pedestrian catchments for user-specified destinations utilising a crowd-source road network and open topographic data.	University	Australia	Simulation tool (app). Two case studies are conducted to demonstrate the technical feasibility and flexibility using the proposed evaluation approach and explain how new renewal strategies can be tested when designing a more inclusive neighbourhood.	Without accounting for topography, the accessibility model has been constrained to overly simplified and inaccurate circular catchment buffers.	The PedestrianCatch tool has proven effective and flexible, providing a platform for a diverse group of stakeholders to test a variety of urban scenarios for promoting an inclusive neighbourhood, in this case, parks and gated communities; however, it could also be applied to scenarios seeking to select the optimal location of new amenities, aged care facilities, housing for disability communities, or medical facilities, and impacts of potential urban interventions to increasing catchments.

Table A2. *Cont.*

Author	Year	Brief Name	Why	What	Who	Where	When and How Much	Tailoring	How Well
Zhang, H., Song, X., Long, Y., Xia, T., Fang, K., Zheng, J., . . . & Liang, Y. [18]	2019	Mobile phone GPS data in urban bicycle-sharing: Layout optimization and emissions reduction analysis	Bicycle-sharing is an up-to-date travel mode and has been introduced to many cities worldwide. As a popular form of urban transport, public bicycles have the following advantages: as they produce no air or noise pollution, bicycle-sharing systems provide residents and tourists with a convenient, environmentally friendly way to travel, and enhance the city's sustainable competitiveness. Meanwhile, cycling also helps to enhance public health and reduce morbidity levels associated with urban disease. Finally, compared with other public transportation modes, public bicycles have the benefits of small volume, flexible operation, good accessibility, and lower investment cost	In this paper, a model is proposed for analysing the potential reduction in emissions associated with the adoption of a bicycle-sharing system. Methods are proposed for extracting human travel modes from mobile phone GPS trajectories, together with a geometry-based probability model, to support particle swarm optimization. A comparison study is implemented to analyse the model's computational efficiency.	National research institute	Tokyo	Mobile phone GPS trajectories from approximately 3.7 million local mobilities are used to construct a case study for Setagaya Ward, Tokyo. A geometry-based probability model is proposed for uncertainties of the issue. A multi-scenario programming model is proposed for rebalancing operations. A multi-sided sensitivity analysis is made for potential emissions reduction.	Data acquisition in this study was affected by several factors, including loss of signal or battery power, and the difficulty of discriminating between public and private vehicle travel trajectories based on mobilephone GPS data.	The results show that, compared with the previous methods, the optimal layout solved by the proposed method could reduce emissions by a further 6.4% and 4.4%. With an increase from 30 to 90 bicycle stations, the adoption of bicycle-sharing can reduce CO_2 emissions by approximately 3.1–3.8 thousand tonnes. However, emission reduction will maximally decrease by 21.26% after offset by bicycles production and rebalancing-generated emission.

Appendix C

Table A3. Analysis of the scoping review studies.

Author	Year	Location	Analysis Method	Study Population	No. Participants	Measure Applied	Post Evaluation	Health Impact	Transference	Push or Pull
Billones, R.K.C., Guillermo, M.A., Lucas, K.C., Era, M.D., Dadios, E.P., & Fillone, A.M. [27]	2021	Western Visayas, Philippines	Data flow architecture to detect Smart cities and smart regions: coverage map, surveys, GPS, inventory of public transportation system.	The multimodal regional transportation networks and social services infrastructure of 6 provinces, 16 cities, and 114 municipalities.	1,831,864	(C) "Sustainable Technology-Assisted Route Planning for Region VI (STARPLAN-VI)" project, which includes local public transportation route planning and development of ITS technology platforms.	No, the network effects of smart cities in regional urban and rural development will be considered in succeeding research. This is a 2-year study.	Yes	Yes, develops an integrate ATIS for land, sea, and air transportation.	Push
Cambra, P., & Moura, F. [29]	2020	Lisbon, Portugal	Paired t-tests	Individuals who lived, worked, or visited the intervention area.	802 individuals were surveyed; pedestrian volume counts are not specified.	(B) Street improvement intervention.	Yes, but only for pedestrian volume.	No	No	Push
Cerutti, P.S., Martins, R.D., Macke, J., & Sarate, J.A.R. [26]	2019	Passo Fundo, Brazil	Survey plus descriptive and factorial analysis with SPSS. Finally, the analysis of variance (ANOVA).	Passo Fundo residents.	526 residents: 266 users, 260 non-users.	(A) A program that consists of an automatic bicycle lending system, based on the sharing experience.	No	Yes	Yes, transferring this type of study to another smart city.	Push
Chatziioannou, I., Alvarez-Icaza, L., & Bakogiannis, E. [23]	2020	Mexico City, Mexico	Analysis of sensitivity. Build a global index and structural analysis. MICMAC method.	UTI-urban surrounding elements.	-	(D) The three strategies of Mexico City's PIM (integrate, improve, and protect)	No	Yes	No	Push and Pull

Table A3. *Cont.*

Author	Year	Location	Analysis Method	Study Population	No. Participants	Measure Applied	Post Evaluation	Health Impact	Transference	Push or Pull
Egiguren, J., Nieuwenhuijsen, M.J., & Rojas-Rueda, D. [20]	2021	17 countries	Quantitative health impact assessment.	Urban residents between 20 and 64 years old.	Full urban population of each country.	(A) Bicycle trips replace car trips in several 2050 global scenarios.	No	Yes	Yes	Push
Izquierdo, R., Dos Santos, S.G., Borge, R., de la Paz, D., Sarigiannis, D., Gotti, A. & Boldo, E. [30]	2019	Madrid, Spain	Standardised HIA methods (health impact assessment).	Annual mean concentrations ($\mu g/m^3$) of PM2.5, NO_2 and O_3. Residents of Madrid.	-	(D) Madrid city air-quality plan.	Yes	Yes	no	Pull
Jung, H., Lee, S.Y., Kim, H.S., & Lee, J.S. [16]	2018	Seoul, South Korea	Multilevel regression.	Individuals passing through the survey locations.	35,424 individuals were surveyed; pedestrian counts are not specified.	(B) Street improvement intervention.	Yes	No	No	Push
Maisel, J.L., Baek, S.R., & Choi, J. [19]	2021	Village of Williamsville, New York	Ordinal logistic regression	18 years old or older individuals passing by on the Main Street of the village	148 (pre) and 102 (post) individuals	(B) Complete Streets, a street improvement intervention.	Yes	Yes	No	Push
Marcheschi, E., Vogel, N., Larsson, A., Perander, S., & Koglin [17]	2022	Malmö and Gothenburg, Sweden	*t*-test, ANOVA, Tukey's HSD and hierarchical regression.	Residents and users of place.	1049 residents and 90 users of place.	(C) Car-free street interventions, which restrict car traffic.	No	No	No	Pull
Mateu, G., & Sanz, A. [25]	2021	Valencia, Spain	Traffic comparison of the same spots between years.	Individuals who drive any kind of metal vehicle and pass over a bicycle lane equipped with a sensor.	-	(A) Wide set of bicycling promotion public policies.	Yes	Yes	No	Push
Mueller, N., Rojas-Rueda, D., Khreis, H., Cirach, M., Andrés, D., Ballester, J., . . . & Nieuwenhuijsen, M. [24]	2020	Barcelona, Spain	Comparative risk and quantitative health impact assessments.	Barcelona residents who are 20 years old or older and lives in a projected superblock area.	1,301,827 individuals and 503 projected superblock areas.	(C) Superblock model: traffic restrictions policies and LEZ implementation (low emission zone).	No	Yes	Yes	Pull
Otero, I., Nieuwenhuijsen, M.J., & Rojas-Rueda, D. [21]	2018	Europe	Quantitative health impact assessments.	Individuals' responses to several Transport and Health surveys and Environmental and Safety official records	Full urban population of each city	(A) Bicycle trips replace car trips in several scenarios	No	Yes	Yes	Push
Reche, C., Tobias, A., & Viana, M. [28]	2022	Europe	Long-linear model.	Concentrations of NO_2 and PM2.5 from 2007 to 2016.	-	(C) Several measures to reduce traffic: fostering active transport modes, redistribution of public space, promotion of public transport, traffic policies/taxes, technological improvement/road management, creation of LEZ.	Yes	Yes	No	Push and Pull
Rodriguez-Rey, D., Guevara, M., Linares, M.P., Casanovas, J., Armengol, J.M., Benavides, J., . . . & García-Pando, C.P. [31]	2022	Barcelona, Spain	Traffic emission model HERMESv·, mesoscale air quality system CALIOPE and street scale air quality system CALIOPE-Urban.	NO_2 concentration levels in Barcelona.	About two million inhabitants, 6000 vehicles/km^2.	(C) Superblock model: traffic restrictions policies and LEZ implementation (low emission zone).	Yes	Yes	No	Pull
Tao, J., & Zhou, Z [22]	2021	Shanghai, China	LCA (life cycle assessment) and scenario model.	Different transport methods in Shanghai and their behaviour in terms of transport time, emissions, public space occupation.	-	(A) DBS, implementation of the Dockless Bike-sharing Service in Shanghai.	Yes	Yes	Yes, it explains how to adapt the method in other Chinese environments.	Push
Zhang, H., Song, X., Long, Y., Xia, T., Fang, K., Zheng, J., . . . & Liang, Y. [18]	2019	Tokyo, Japan	Multi-scenario integer linear programming model.	Anonymous GPS trajectories from 2012 walk, bicycle, and car trips.	3,659,703 trajectories.	(A) Optimization of bicycle sharing stations.	No	Yes	Yes	Push

A = Measures to promote the use of bicycles. B = Interventions to improve streets and public spaces. C = Reduction and/or optimization of motorized transport. D = Plans for mixed urban measures.

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