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Ranking sustainable urban mobility indicators and their matching transport policies to support liveable city Futures: A MICMAC approach

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A R T I C L E I N F O

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A B S T R A C T

Understanding, promoting and managing sustainable urban mobility better is very critical in the midst of an unprecedented climate crisis. Identifying, evaluating, benchmarking and prioritising its key indicators is a way to ensure that policy-makers will develop those transport strategies and measures necessary to facilitate a more effective transition to liveable futures. After identifying from the literature and the European Commission (EC) directives the indicators that are underpinning the powerful scheme of Sustainable Urban Mobility Plans (SUMPs) that each municipality in Europe may implement to elevate the wellbeing of its population, we adopt a Cross Impact Matrix Multiplication Applied to Classification (MICMAC) approach to assess, contextualise and rank them. Through conducting a qualitative study that involved a narrative literature review and more importantly in-depth discussions with 28 elite participants, each of them with expertise in sustainable development, we are able to designate the Sustainable Urban Mobility Indicators (SUMIs) that are the most (and least) impactful. According to our analysis the most powerful indicator is traffic congestion, followed by affordability of public transport for the poorest, energy efficiency, access to mobility service and multimodal integration. This analysis allows us to then match them with the most applicable strategies that may ensure a holistic approach towards supporting in practical terms sustainable mobility in the city level. These are in ranking order: Transit Oriented Development (TOD); public and active transport enhancement; parking policies, vehicle circulation and ownership measures; telecommuting and car-pooling.

1. Introduction

The concept of sustainable development is a critical issue for urban planners and policy-makers since the publication of the Brundtland report back in 1987 (Mensah, 2019). Since we now live in an era where the impacts of climate change are getting more and more serious, it is time to plan our cities accordingly (Gandini et al., 2021). Sustainability has three essential axes: the environmental, the social and the economic one and all of them are linked with transport. More specifically, the problem of excessive automobile usage along with its associated (un-) sustainable effects is widely acknowledged as a primary sustainability concern (Alyavina et al., 2022). Urbanisation and the consequent expansion of cities encourage even more the use of automobiles, thus creating a car-centric vicious circle (Silva and Teles, 2020; Tsigdinos et al., 2022).

Therefore, managing transport activities adequately is critical in the pursuit of sustainable development. On the one hand, transport is a key element in shaping an area's economic health and quality of life (Politis et al., 2021a) as it offers the necessary infrastructure for passengers and freight mobility, allowing people to perform several everyday activities,

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such as: studying, working and shopping (Musselwhite et al., 2021). Moreover, transport via the high tensed usage of its infrastructure, is an essential component for productivity, output, growth rate and economic development (Melo et al., 2013). On the other hand, transport generates several negative externalities such as congestion, traffic accidents, noise, greenhouse gases and various distinct pollutants that could have severe social, environmental and health costs (Loo and Banister, 2016; Santos et al., 2010; Zhao, 2010).

Furthermore, the long commuting times can reduce social cohesion and the participation of people within their communities (Putnam, 2000). For instance, the work of Hart (2008) provides substantial evidence that the regions of light traffic that promote active modes such as walking and cycling present high rates of sociability compared to areas of medium and heavy traffic. Also, the devaluation of public space, because of the extensive use of private motorised vehicles, affects severely the attractiveness and image of a city, as well as the culture of its local population (Kyriakidis et al., 2017). Hence, transport and urban planning systems need to nurture sustainable mobility principles via improvements based on eco-friendliness, participation, accessibility, and social inclusion.

Nowadays, the cities of Europe should reconsider their future transport development strategies. The European Union's (EU) Green Deal (Wolf et al., 2021) is their new policy benchmark so that they can meet the objective of 90 % reduction in greenhouse gas emissions from transport activities and reach a zero-carbon reality by 2050. Furthermore, due to COVID-19, new challenges came to surface and highlighted the need to generate safe travel conditions, reshaping urban design and transportation systems to support sustainability targets and accommodate more resilient mobility services (Nikitas et al., 2021b; Kyriakidis et al., 2023).

Thus, particularly in Europe, numerous countries, aim to build a more user-centric and eco-friendly urban mobility planning rationale (Mladenovič et al., 2022). A Sustainable Urban Mobility Plan (SUMP) can be described as a scheme looking to establish improved quality of life through enhancing sustainable transport. The centrepiece of a SUMP is the improvement of accessible active mobility and public transport alternatives within the urban area of a city (ELTIS, 2019).

Hence, it is important for the effective SUMPs to explore holistic planning procedures (Charradi et al., 2022). Over recent years, noticeable efforts have been made towards several methodological directions that extend from defining sustainable development (Waas et al., 2010) to designing monitoring indicators (Parris and Kates, 2003). Several studies refer to sustainable development indicators at national level (De Sherbinin and Bittar, 2003), while others consider sustainable development at a city level (Rodrigues da Silva et al., 2015). Despite the fact that both indicator types acknowledge the role and importance of sustainable mobility, this subject is, in general, only partially covered (UNECE, 2013). More holistic approaches are missing. The European Commission (EC) has accordingly created a set of practical indicators that help cities to apply a hierarchical assessment of their mobility systems and to evaluate advances emerging from new mobility strategies, policies and schemes.

In this study we apply a structural analysis-MICMAC method, examining the indicators of SUMPs, as they are defined by EC, so that to understand the interlinks among them. We then identify the most appropriate transport policies that match them and prioritise them according to their relation with the indicators (the more the better) and their overall benefit.

We decided to use the structural analysis-MICMAC, over other participatory methods such as Delphi and Analytic Hierarchy Process (AHP), for several reasons. First MICMAC can consider, except from direct impacts, the indirect ones, being capable of fully exhibiting and clarifying the importance of each indicator. Moreover, MICMAC can assign weights to the considered indicators, through a normalisation process for influence and dependence rates, and therefore generate, if needed, a priority score for each variable. Finally, another advantage of MICMAC compared to alternative methods is the ability to determine the hierarchy of strategic variables of a system and to identify their mutual effects. This feature is useful to the policy selection process as it ensures efficiency and coherence.

Our paper supports the effort to create a novel sustainable mobility assessment, which is capable to contribute to the current literature in two levels. First, by determining the connections between the core SUMIs we get to understand them better. Second, by considering the stakeholder perceptions, through the establishment of expert groups, our paper aims to link the hierarchically organised SUMIs with matching transport policies and prioritise the latter according to the effects that these would have on SUMIs and the society.

The research aim of this work is thus: *"To identify, contextualise and rank the key SUMIs via a qualitative-prospective method according to their importance and match them with appropriate transport strategies and policy instruments that would be also ranked."*.

The structure of the paper is as follows. Section 2 presents the indicators related to SUMPs and several sustainable transport policies. Section 3 describes the method used to determine the interrelation between the indicators and applies structural analysis to rank them according to their importance. Section 4 shows the results and the analysis of the structural analysis implementation. Section 5 provides a critical discussion of our findings and Section 6 presents the conclusions of the paper, its limitations and future research directions.

2. SUMIs and sustainable transport policies

An essential factor for the development of sustainable urban mobility, is the offering of secure, affordable, reliable and comfortable mobility alternatives for all users, resulting in fewer road crashes, cleaner air, reduced commuting and energy demand decrease (Nikitas, 2018). However, the future of urban transport is uncertain and complex (Tsigdinos et al., 2022). The formulation of Sustainable Urban Mobility Indicators (SUMIs), capable of measuring and assessing potential solutions, is thus the key in addressing transport problems. SUMIs would prioritise people over cars establishing a new hierarchy where priority is given to sustainable transport modes such as walking, cycling and public transport (Tsigdinos and Vlastos, 2021).

Based on the paradigm of sustainable mobility described by Banister (2008), the EC has developed a comprehensive set of practical indicators that supports cities to perform a standardised evaluation of their mobility system. These indicators were structured around four dimensions. The first three dimensions relate to the concept of sustainable development and specifically to *the environment, quality of life*, and *economic performance* (United Nations, 2002). The *performance of the mobility system itself* is the fourth dimension. This dimension tries to establish a systemic approach, based on the quality and status of mobility, explained in an integral way through different fields that coexist within the mobility system and in which, mobility accords can be established (Egeter and van de Riet, 1998). Based on these dimensions we conducted a thematic narrative literature review (conducted in line with best practice examples e.g., Nikitas et al., 2021a) that helped us identify the following indicators framed in Fig. 1.

Fig. 1 portrays a set of indicators which incorporate "traditional" criteria, like noise reduction, road deaths, local air pollution and greenhouse gas emissions, with more innovative criteria, such as accessibility of public transport for mobility impaired groups, active mobility opportunities and affordability of public transport. This combination of criteria perhaps reveals the true multifaceted character of sustainable mobility. Nevertheless, this approach can be further enhanced by identifying the relationships between the indicators as they are based upon interrelated components of the mobility system; this could allow the assessment of possible measures towards more effective sustainable mobility based upon the co-benefits that would occur through their joint implementation. A well-orchestrated mobility management approach can generate incentives to reduce private car use and

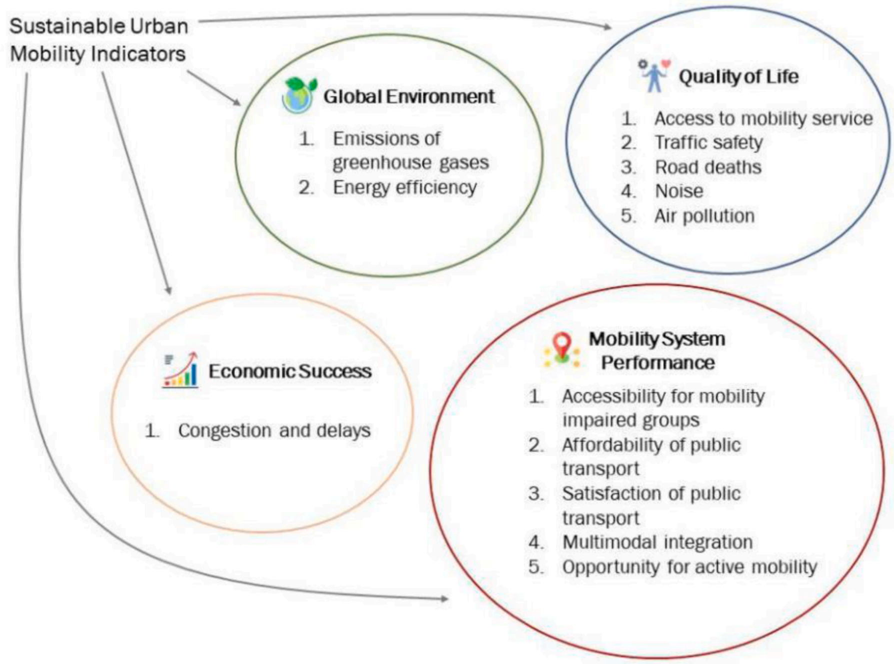

Fig. 1. SUMIs in a glance.

promote the use of non-motorised transport and public transport. The key strategies and policies for enhancing sustainable urban mobility, derived from our review, are presented in Fig. 2.

3. Methodology: The Structural Analysis-MICMAC method

Structural analysis is a prominent instrument in the field of prospective studies and has been implemented for the first time in 1961 by Jay Forrester in his work with models of urban and industrial dynamics (Arcade et al., 1994). Throughout the years structural analysis has been implemented in many fields such as industrial development, where it was utilised to evaluate the performance of an iron-steel company (Wanty and Federwish, 1969). Shortly after Teniere-Buchot, applied structural analysis to analyse the "water" system and mitigate water pollution via the corresponding public policies (Arcade et al., 1994). Furthermore, Roberts led works for the United States National Foundation of Sciences to discover relationships among applications related to energy and pollution in the sector of transport (Roberts, 1971).

Duperrin and Godet (1973) proposed a MICMAC approach for nuclear energy systems. More recently, Sharma et al. (1995), considered

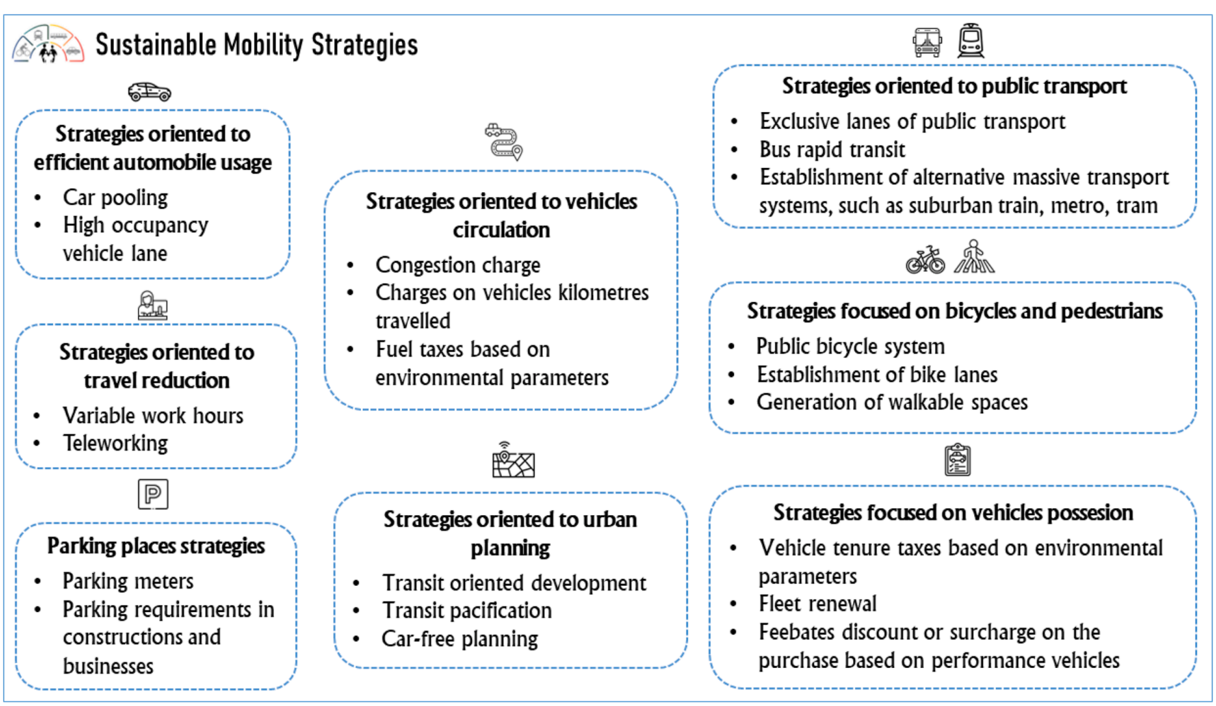

Fig. 2. Transport strategies and policy instruments enhancing sustainable mobility.

waste management with structural analysis. Furthermore, structural analysis has been utilised to assess the performance and the effectiveness of information systems (Kanungo et al., 1999), while Arya and Abbasi (2001) demonstrated a method of environmental assessment through structural analysis. In addition, international relationships approaches have been combined with the method of structural analysis to determine, distinguish, and comprehend the nature of international conflicts (Kim and Barnett, 2007), Also, Qureshi et al. (2008) and Chatziioannou et al. (2020b) utilised the method of structural analysis for the publication and promotion of 3PL provider's services guidelines and the hierarchical organisation of public policies related to the mitigation of climate change in the North Aegean Region of Greece.

Recently, structural analysis-MICMAC has been used in transport studies with success, as it helped to assess and rank some of the negative externalities of transport (Chatziioannou et al., 2020c) and promote policies that would make the implementation of Mexico Citýs integral plan of mobility more successful (Chatziioannou et al., 2020d). Lastly, structural analysis has been utilised to hierarchically organise certain elements of urban transport infrastructure aiming to construct a synthesised index that calculates the quality of sustainable mobility based on urban management and design components (Chatziioannou and Alvarez-Icaza, 2017).

The method of structural analysis is a tool used to identify and study system correlations so that to prioritise the pivotal variables or indicators for the functionality and evolution of the system. In other words, it enables the identification and systematic organisation of all the key indicators via a matrix that presents their interrelations and clearly showcases their unique significance for the system. That is why structural analysis can be implemented, in a wide variety of sectors, when the selected variables of the system under study are interrelated and are not isolated components.

The structural analysis method includes three steps:

Step 1: Creating an *inventory* of the system's factors-indicators.

Step 2: Describing the interlinks between the system's factors.

Step 3: *Identifying* pivotal factors-indicators.

MICMAC was adopted due to its unique ability per Khan and Haleem (2012) to:

a) *enable* the smooth operation of the system under study, through the identification of the pivotal indicators that need to be considered within the analysis of the system;

b) enrich the planning process by considering expert perceptions within the design process;

c) allow a comprehensive analysis of the system indicators;

d) correlate and organise the identified indicators in order of importance;

e) support the identification of "hidden" factors, that could play an important role for the systems operation, via the understanding of indirect relationships among the components of the system that were not identifiable via direct classification.

However, the Structural analysis-MICMAC method has also some limitations that should be acknowledged. Firstly, as any method encouraging team approaches, structural analysis is significantly based on the participants selection. In fact, the results can be strongly biased by dominating competencies within the expert group. Hence, it is vital to establish a multidisciplinary sample so that the relations among the variables will not be affected. Secondly, implementing a structural analysis is a rather heavy-duty process demanding human resources and experts' availability, and can last up to six months. Thirdly, structural analysis needs the size of the participating experts' team to be small; no more than 12 people. Otherwise, the liveliness of the process becomes complicated and potentially tiresome, at such a level that the quality of the work along with its result, can be in jeopardy. Therefore, it is advisable to tackle this issue, for groups consisting of more than 20 people, via the creation of two or more subgroups; we did that.

4. Results and analysis

This section explores SUMIs as defined by the EC to identify the most effective policies according to the expected benefits generated by their implementation.

4.1. Inventory of the system's factors-indicators

The first step considers the creation of a table with the core SUMIs as established by EC. These indicators have been identified through literature review and are key factors underpinning sustainable mobility (see Table 1).

4.2. Description of the interlinks between the systems factors

The aim of this step is interrelating the established SUMIs through a matrix that exposes at a row level the grade of influence of an indicator on the other indicators. Meanwhile, the matrix at a column level expresses the dependence that a particular indicator experiences by the other indicators within the system (Chatziioannou et al., 2020b). In the classic structural analysis implementation, every pair of indicators needs to be assessed according to their interlinks. Hence, the existence of no relationship betewen two indicators is noted with 0; alternatively, the existence of a relation between two indicators should be characterised in terms of intensity (i.e., strong, medium and weak) or as potential according to its nature (Ballesteros Riveros and Ballesteros Silva, 2008). In our study we decided to utilise only two values: zero ("0″) expresses a no relationship and one ("1") notes a relationship between the pair of indicators. We decided to do so, with the aim to keep the consultancy process as simple as possible.

This matrix has been created by a consulting process with 28 independent experts, all of them with substantial interdisciplinary experience. The process has been separated into seven stages. The first stage refers to the creation of the matrix (by us), excluding the experts' perspective; in this phase an extensive literature review was conducted helping the authors to identify the interrelationships between the selected indicators. In stage 2 the group of experts was assembled. We used an e-mail invitation to recruit the experts and prepared and used a brief presentation concerning the nature of the study, the research aim and the method used; this strategy helped us achieve higher response rates.

The sample of experts includes geographers, urban planners, transport engineers, environmentalists and policy-makers. According to best practice we divided the 28 experts in three groups of 10, 9 and 9 participants respectively. We created a pool of participants as multidisciplinary as possible, to promote diversity, avert leader's phenomena and reduce bias.

Table 1
The identified indicators (SUMIs) for the case study.

ID	Nomenclature of SUMIs	Codename for SUMIs (Software MICMAC)
1	Affordability of public transport for the poorest	Affordabil
2	Accessibility of public transport for mobility impaired groups	Accessibil
3	Air pollutant emissions	Air_pollut
4	Noise hindrance	Noise
5	Road deaths	Road_death
6	Access to mobility service	Ac_mob_ser
7	Greenhouse gases	GHG
8	Congestion and delays	Congestion
9	Energy efficiency	Energy_eff
10	Opportunity for active mobility	Op_act_mob
11	Multimodal integration	Multi_inte
12	Satisfaction with public transport	Satis_PT
13	Traffic safety	Traff_sfty

Table 2
Matrix of direct influences and dependencies.

	1: Affordability	2: Accessibility	3: Air pollution	4: Noise	5: Road deaths	6: Access to mobility service	7: GHG	8: Congestion	9: Energy efficiency	10: Opportunity for active mobility	11: Multimodal integration	12: Satisfaction with public transport	13: Traffic safety	**Total score of influence (y axis)**
1: Affordability	0	1	0	0	0	1	0	0	0	0	1	1	0	**4**
2: Accessibility	0	0	0	0	0	1	0	0	0	1	0	1	0	**3**
3: Air pollution	0	0	0	0	1	0	1	0	0	0	0	0	1	**3**
4: Noise	0	0	1	0	0	0	0	0	0	0	0	0	0	**1**
5: Road deaths	0	0	0	1	0	0	0	1	0	0	0	0	1	**3**
6: Access to mobility service	0	0	1	0	1	0	1	1	1	1	1	1	1	**9**
7: Greenhouse gases	0	0	1	0	0	0	0	0	1	0	0	0	0	**2**
8: Congestion	0	0	1	1	1	0	1	0	1	0	0	1	1	**7**
9: Energy efficiency	0	0	1	1	0	0	1	0	0	1	1	0	0	**5**
10: Opportunity for active mobility	0	1	1	1	0	0	1	0	0	0	0	0	1	**5**
11: Multimodal integration	0	1	1	1	1	0	1	1	0	1	0	1	1	**9**
12: Satisfaction with public transport	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
13: Traffic safety	0	0	0	1	1	0	0	1	0	1	0	1	0	**5**
Total score of dependence (x axis)	**0**	**3**	**7**	**6**	**5**	**2**	**6**	**4**	**3**	**5**	**3**	**6**	**6**	

Table 3
The composition of the expert panel.

Group 1 ID	Area of Expertise	Group 2 ID	Area of Expertise	Group 3 ID	Area of Expertise	Expert Roles – Reasons for their Inclusion in the Sample
Expert 1	Geographer	Expert 1	Geographer	Expert 1	Geographer	To highlight the way the urban space and built environment should be shaped for creating solutions towards the promotion of the sustainable mobility paradigm.
Expert 2	Geographer	Expert 2	Geographer	Expert 2	Geographer	
Expert 3	Urban Planner	Expert 3	Urban Planner	Expert 3	Urban Planner	
Expert 4	Urban Planner	Expert 4	Urban Planner			
		Expert 5	Urban Planner			
Expert 5	Transport Engineer	Expert 6	Transport Engineer	Expert 4	Transport Engineer	To investigate the need of using road capacity more effectively, by utilising intelligent transport systems to improve the performance of the existing transport modes.
				Expert 5	Transport Engineer	
Expert 6	Mobility Planner	Expert 7	Mobility Planner	Expert 6	Mobility Planner	To identify the character that public transport has in the enhancement of mobility systems performance and the support of mobility paradigm.
				Expert 7	Mobility Planner	
Expert 7	Mobility Planner			Expert 8	Mobility Planner	
Expert 8	Accessibility Planner	Expert 8	Accessibility Planner	Expert 9	Accessibility Planner	To recognise the importance of multimodality, as well as the significance of proximity of multiple points of interest so that people cover their mobility needs without using cars and the promotion of mixed land use towards the creation of compact cities.
Expert 9	Accessibility Planner					
Expert 10	Environmentalist	Expert 9	Environmentalist	–		To identify the environmental footprints deriving from the excessive car usage and highlight the need for addressing the climate crisis.

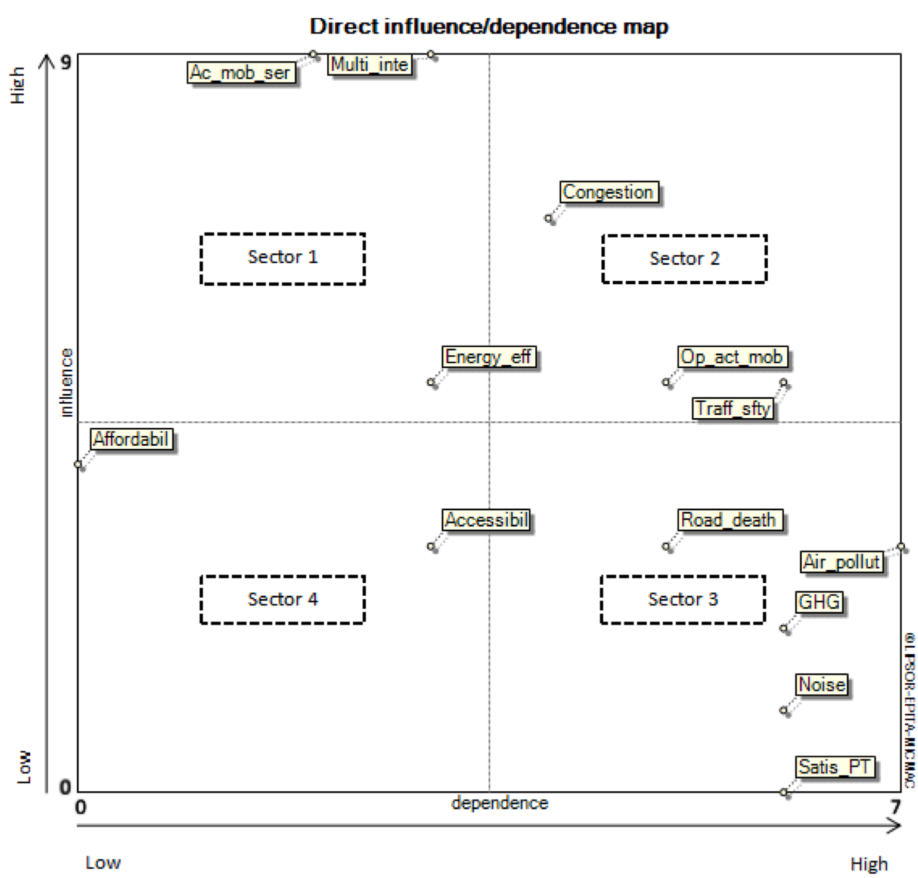

Fig. 3. The location of variables as they result from the matrix of direct influences-dependencies.

Stage 3 included the first data collection engagement between the three groups of experts and the authors via Zoom meetings. In this stage we tried to distinguish relationships among the indicators, and fill the matrix presented in Table 2. This stage also highlighted the need to explain, in detail, the interlinks between the SUMIs. Thus, the initial literature review that we conducted before meeting the experts helped considerably to save time and effort at this research stage. The steps followed for filling in the matrix of Table 2 as per Arcade et al. (1994) are: a) selection of all the indicators that belong within the system under study; b) identification of indicators that experience no influence (filling up the matrix with "0" is done line by line); c) determination of indicators that do exert influence upon the rest of the considered indicators (filling up the matrix with "1" is done line by line); d) identification of factors that are closely intertwined; e) repetition of the process until no indicator is left unchecked in terms of influence and dependence; f) transcription of direct influences in the MICMAC free software designed by Michel Godet.

Stage 4 considers the implementation of the Sussman criteria (i.e., type of influence, direction of influence and justification of influence) to explain the features of the interrelations among the SUMIs. In Stage 5 the experts, unprompted, tried to relate SUMIs with policy mechanisms designed for enhancing sustainable mobility.

Stage 6 refers to discussing further the connections between SUMIs and sustainable mobility strategies and policy instruments and eventually matching them; this gave us the opportunity to rank SUMIs in order of importance and therefore contributed to building a hierarchical categorisation of several public policies and strategies related to sustainable mobility. In this stage using a literature review, we presented a wide range of available sustainable mobility strategies and specific policy measures (as illustrated in Fig. 2) and their effects to the expert groups. By being exposed to these policy measures and having the opportunity to reflect on their sustainability value, experts were then able to generate links between each policy and the selected SUMIs.

The final stage (stage 7) was about establishing a consensus among the experts, regarding the importance of the selected indicators within a sustainable mobility framework. The mix of the expert panel is presented in Table 3.

The 28 experts (i.e., our elite sample) are from Europe and Americas and were chosen because of their expertise in sustainable mobility and urban development. Some of them are politicians with extensive knowledge in SUMP design, promotion and implementation, while others are researchers with high-quality publications in the field of sustainable transport planning. This sample size is satisfactory and well in line with best practice guidelines and published MICMAC literature (Al-Esmael et al., 2019; Arcade et al., 1994; Jain et al., 2018; Khatwani et al., 2015). According to those readings a single group of 12 experts is accepted as sufficient in producing valid and reliable results.

4.3. Identification of pivotal factors-indicators

This step enables the identification of the most important indicators (in respect of influence and dependence grades) through the calculation of direct and indirect interlinks within the system (Colodni, 1987). The direct classification can be achieved by summing up the components (zeros and ones) in each row and column level. For instance, the indicator of air pollution exerts an influence grade equal to 3 (see Table 2) as it affects three indicators, while it has a dependence rate equal to 7, as it is influenced by seven indicators. Hence, the descriptive image of the above sums can be seen in Fig. 3 along with the location and hierarchical organisation of each indicator according to the direct relationships between them. This map has two axes, where the X axis refers to the dependence level and the Y axis to the influence level. The maximum values of influence and dependence are the access to mobility service (Ac_mob_ser) and air pollution (Air_pollut) whose sums are equal to 9 and 7 respectively.

Fig. 3 shows that the most influential variables (seen in Sector 1) are energy efficiency, access to mobility services and multimodal integration. Sector 2 hosts those variables that not only are influential but dependable as well. In this category-one can found some "key" variables such as traffic congestion, traffic safety and opportunity for active

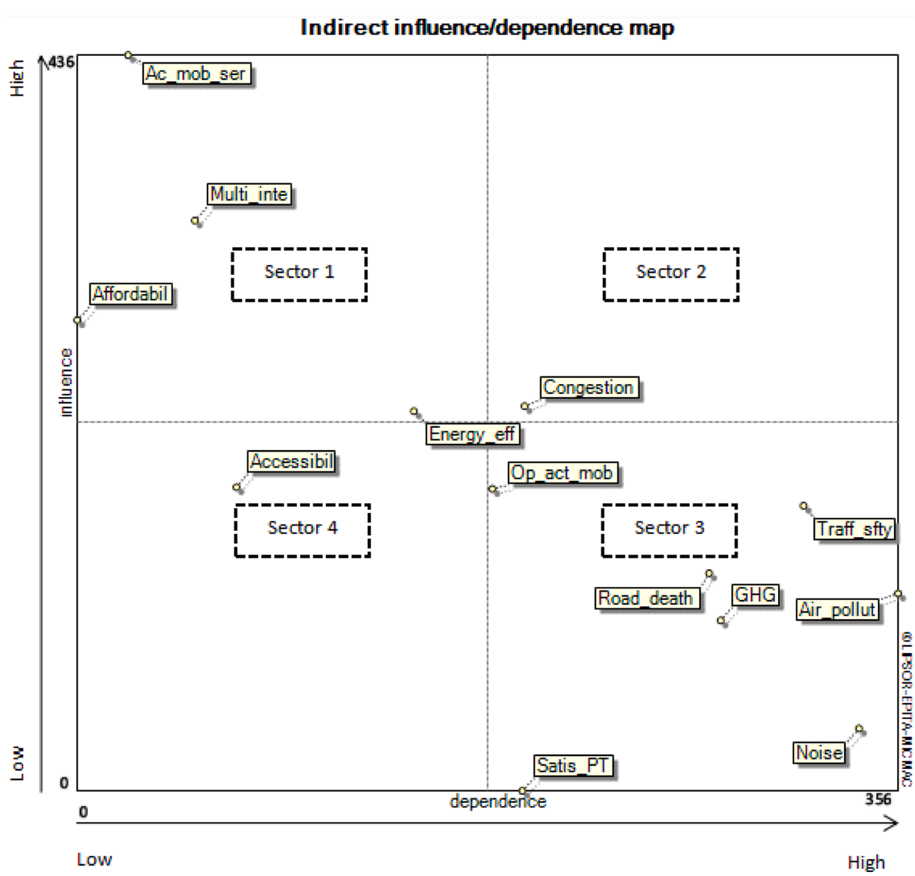

Fig. 4. The location of indicators as they result from the matrix of indirect influences-dependencies.

Table 4
Justification of the relationships between the SUMIs.

ID	Core SUMIs	Directly Related SUMIs
1	Affordability of public transport	Accessibility of PT for mobility impaired, access to mobility service, multimodal integration, satisfaction with PT (Cats et al., 2017; El-Geneidy et al., 2016; Santos et al., 2020; Shrestha et al., 2017).
2	Accessibility of public transport for mobility impaired people	Access to mobility service, opportunity for active modes, satisfaction with PT (El-Geneidy et al., 2016; Metz, 2000; Redman et al., 2013; Sarker et al., 2019; Shrestha et al., 2017).
3	Air pollution	Road deaths, traffic safety, GHG (Chatziioannou et al., 2020a; Sager, 2019; Timilsina and Shrestha, 2009).
4	Noise	Air pollution (Chatziioannou et al., 2020a; Shepherd et al., 2016; Stansfeld, 2015).
5	Road deaths	Noise, congestion, traffic safety (Chatziioannou et al., 2020a; Racioppi et al., 2004).
6	Access to mobility service	Air pollution, road deaths, traffic safety, GHG, congestion, satisfaction with PT, energy efficiency, opportunity for active modes, multimodal integration (AlKheder, 2021; Friman et al., 2020; Inturri et al., 2021; Joewono and Kubota, 2006; Kumar et al., 2013; Le and Tu, 2016; Litman, 2021; Litman, 2012b; Litman, 2010; Nguyen-Phuoc et al., 2020; Vale, 2021; Woldeamanuel and Cygansky, 2011).
7	GHG	Air pollution, energy efficiency (Chatziioannou et al., 2020a; Ramanathan and Feng, 2009).
8	Congestion	Air pollution, GHG, energy efficiency, noise, road deaths, traffic safety, satisfaction with PT (Albalate and Fageda, 2021; Bharadwaj et al., 2017; Chatziioannou et al., 2020a; Kellner, 2016; Pawlasová, 2015; Zhang and Batterman, 2013)
9	Energy efficiency	GHG, air pollution, noise, opportunity for active mobility (Akdag and Yıldırım, 2020; Borén, 2020; CRES, 2015; Gillingham et al., 2021; Oeschger et al., 2020)
10	Opportunity for active mobility	Air pollution, noise, traffic safety, GHG, accessibility to public transport for mobility impaired people (Koszowski et al., 2019; Lozzi and Monachino, 2021; Metz, 2000; Mizdrak et al., 2019).
11	Multimodal Integration	Air pollution, noise, GHG, accessibility to PT for mobility impaired, opportunity for active mobility, satisfaction of PT, congestion, road deaths, traffic safety (Chauhan et al., 2021; Cottrill et al., 2020; Kim et al., 2018; Kumar et al., 2013; Litman, 2021; Litman, 2013).
12	Satisfaction with public transport	There is no direct influence in our results. * Satisfaction of public transport users can modify travel habits and make people seek a shift from the private car to other modes, bringing about all the positive effects associated with this shift such as reduction of air pollution - greenhouse gases, energy efficiency, mitigation of traffic congestion (Alyavina et al., 2020). However, these positive effects are indirectly and not directly related to the indicator.
13	Traffic safety	Noise, road deaths, opportunity for active mobility, congestion, satisfaction with PT (Mladenovič et al., 2022; Joewono and Kubota, 2006; Laverty et al., 2021; Nieuwenhuijsen, 2021; Pawlasová, 2015).

mobility that are pivotal for the shift towards sustainable mobility. Sector 3 includes variables such as noise, road deaths, air pollution, GHG and the satisfaction of users with public transport. These variables are highly dependable on the rest indicators and highlight the necessity to move away from the automobiles̋ overuse. Finally, Sector 4 presents two variables, affordability of public transport and accessibility of public transport to mobility impaired people, that relate to the backbone of sustainable mobility which is public transport.

On the other hand, the indirect classification of variables is the product of elevating the matrix of direct relations to successive powers until its stabilisation. The latter is achieved when the classification of variables both in terms of dependence and influence is constant between different power elevations. For instance, in our case, the matrix has been stabilised after four elevations. This means that if we had continued elevating to the sixth, seventh, eighth power the results and the classification of variables would remain unaffected. The process of power elevation of the matrix until it stabilises includes the following phases:

- Phase 1. Establishment of experts' panel.
- Phase 2. Identification of the relationships of direct nature among the indicators of the system.
- Phase 3. Hierarchical organisation of indicators according to their rates of dependence and influence.
- Phase 4. Presentation of the SUMIs in a logical map according to their level of direct relationships.
- Phase 5. Elevation of the matrix of direct relationships to the square to get the indirect relations of second order.
- Phase 7. Classification of the indicators in terms of direct and indirect influence and dependence.
- Phase 8. Comparison between the matrix of direct relationships and the matrix of indirect relationships so that to rank the associated indicators located in each matrix.
- Phase 9. Does the ranking of the system's indicators remain in the same order?
- Phase 10. If the hierarchical organisation of indicators remains the same in two consecutive matrices (i.e., between matrix^n and matrix^{n+1}) then the stabilisation has been accomplished and we have the final indirect relationship matrix. If not, the matrix should be elevated to consecutive powers until each indicatoŕs ranking, related to influence and dependence grades between the power n and power $n + 1$, remains in the same order (i.e., there is no change in the SUMIs ranking).

The indicators of the system when the matrix is stabilised are presented in Fig. 4 considering both direct and indirect relations between SUMIs. Hence, Fig. 4 is the definitive graph presenting the location and categorisation of SUMIs, as it reflects the true significance of each indicator. Therefore, Fig. 4 presents changes in the categorisation of variables in comparison to Fig. 3. More specifically the variable of affordability of public transport is, after considering direct and indirect relationships among variables, a highly influential component for sustainable mobility. In particular, this variable in conjunction with other similar ones such as comfort, safety and higher frequency of routes can attract people from their private car to public transport. In addition, the variables of traffic safety and opportunity for active mobility have been transformed into highly dependable as they can be easily affected by the rest of the considered variables, such as multimodal integration, congestion, access to mobility services and energy efficiency.

4.4. Justification of the interlinks among SUMIs

This final part of our analysis is about benchmarking the identified interlinks between SUMIs against the literature. Table 4 presents a critical summary of this review process. The rationale behind the table, is to align each specific indicator in the second column with a third column describing all the SUMIs that are directly related to it. For example, the indicator of *affordability of public transport* directly influences, and is thus related to, the indicators of accessibility of public transport for mobility impaired people, access to mobility service,

Table 5
Strategies for the reduction of automobile dependence and efficient automobile usage.

ID	Public policies	Policy definition	Policy Nature	Positive Effects	Interlinked SUMIs
Strategies Focusing on Efficient Automobile Usage					
1	Car-pooling (Bruglieri et al., 2011; Park et al., 2018).	Carpooling is a transportation approach that is oriented towards the collective utilization of private automobiles	Planning-Economic	-Reduces car usage -Reduces congestion -Reduces travel times -Reduces emissions -Promotes sustainable modes -Promotes social interactions -Improves the image of companies -Improves productivity and employees' satisfaction -Reduces companies' costs	- Air Pollution - Green House Gases - Congestion - Energy efficiency
2	High occupancy vehicle lanes. (Daganzo and Cassidy, 2008).	High Occupancy Vehicle lanes are sectors on highways and avenues which can be used by vehicles with multiple commuters during all day or some part of the day.	Regulation	-Reduces car usage -Reduces congestion -Reduces emissions -Promotes efficient land use -Promotes car-pooling	- Air Pollution - Green House Gases - Congestion - Energy efficiency
Strategies Focusing on Travel Reduction					
ID	**Public Policies**	**Policy definition**	**Policy Nature**	**Positive Effects**	**Interlinked SUMIs**
1	Variable Work Hours (ITDP, 2012a).	Variable Work Hours aim to avoid congestion phenomena during peak-period commute travels via a modification in check-in and check-out schedules at work.	Regulation	-Reduces car usage -Reduces congestion -Reduces travel times -Improves habitability -Promotes sustainable modes -Promotes car-pooling -Improves productivity and employees' satisfaction	- Air Pollution - Green House Gases - Congestion
2	Teleworking (Belzunegui-Eraso and Erro-Garcés, 2020; ITDP, 2012a).	Teleworking mitigates the environmental effects of mobility related activities while encourages flexibility and a robust family–work equilibrium	Regulation	-Reduces car usage -Reduces congestion -Improves productivity and employees' satisfaction	- Air Pollution - Green House Gases - Congestion - Noise

multimodal integration and satisfaction with public transport. In the third column of Table 4, we present in brackets published works where the relationships between indicators have been reported. This step was important for the enrichment of our MICMAC approach since it helped us identify the relationships that each specific indicator exerts on other SUMIs and consequently verify the expertś opinion.

4.5. Interlinks between SUMIs and sustainable mobility strategies-public policies

Nowadays, there are different groups of strategies and policy instruments to manage the alternative travel demands derived by the sustainable mobility paradigm (Table 5-8). Through the structural analysis-MICMAC method, this became apparent by the experts. We therefore make a case that these transport strategies-policies should be more clearly interlinked (and eventually matched) with the SUMI indicators. Doing that could facilitate the evaluation, forecasting and monitoring of the joint benefits that their implementation would mean for the society.

This part of the paper, includes a synopsis of our literature review, presented in columns 2–4 of Table 5-Table 8, which provided the opportunity for more insightful talks between us and the experts. The expert participants by being prompted to look at certain policies were able to identify the possible effects of the discussed strategies (column 5 of Table 5-Table 8) and generate links between each policy and the selected SUMIs (column 6 of Table 5-Table 8). Therefore, the columns 2–4 are literature review derived and were presented to our respondents at the latter part of their engagement with us to inform and develop further our conversations. Columns 4–5 on the other hand is a direct product of the MICMAC method and derived after discussions with the experts. These are about understanding the value of policy measures (column 5) and matching them with the suitable SUMIs (column 6). Table 5 presents those policies that intend to establish an efficient automobile usage and trip reduction. Their ultimate goal is to neutralise the negative impacts of motorised transport.

Table 6 considers policies that are associated with the mitigation of cars environmental footprint, not only in terms of vehicle movement, but in terms of vehicle possession as well. Table 7 introduces policies involving the adequate usage of public space (parking and urban planning instruments). Finally, Table 8 demonstrates policies that are destined to facilitate efficient public transport schemes and to promote active mobility alternatives.

5. Discussion

Our paper is a supporting instrument in creating a new brand of sustainable mobility assessment and is capable of contributing to the literature in two levels. First, by determining the connections between the core SUMIs that could ultimately lead to ranking them in terms of importance (something that nowadays is not the case because all the core indicators are treated as equal). Second, by considering experts and enabling them to match SUMIs with real policies, a fact that inevitably

Table 6
Strategies for vehicles possession and vehicles movement.

ID	Public policies	Policy definition	Policy Nature	Positive Effects	Interlinked SUMIs
Strategies Focusing on Vehicles Possession					
1	Vehicle tenure taxes based on environmental parameters. (Wappelhorst et al., 2018)	An imposed tax based upon the possession of a motorised vehicle, considering the negative effects that this vehicle will cause to the environment.	Economic	-Reduces car usage -Reduces emissions -Promotes sustainable modes -Reduces the total number of automobiles -Generates income -Promotes shift to more efficient vehicles	- Air Pollution - Green House Gases - Energy Efficiency - Congestion -Opportunity for active mobility - Access to Mobility Service
2	Feebates, discount or surcharge on the purchase based on performance vehicles (Johnson, 2006).	The feebates consider parameters of energy efficiency through the establishment of payments and discounts, for the purchase of private vehicle.	Economic-Regulatory	-Reduces emissions -Generates income -Promotes shift to more efficient vehicles -Reduces energy consumption -Promotes technological innovation	- Air Pollution - Green House Gases - Energy Efficiency
3	Fleet renewal (Fraire Cervantes, 2011)	This policy is based on the modernization of vehicles fleet in order to neutralize the environmental footprint of obsolete units.	Economic	-Reduces car usage -Reduces emissions -Promotes sustainable modes -Reduces the total number of automobiles -Promotes shift to more efficient vehicles	- Air Pollution - Green House Gases - Energy Efficiency - Congestion -Opportunity for active mobility - Access to Mobility Service
Strategies Focusing on Vehicles Circulation					
ID	**Public Policies**	**Policy definition**	**Policy Nature**	**Positive Effects**	**Interlinked SUMIs**
1	Congestion charge (Litman, 2011a).	The establishment of fares for commuters that circulate within specific parts of a city, at certain times and days. This type of policy also takes into consideration discounts for drivers that use alternative energy fuels (hybrid-electric vehicles), taxis and vehicles of mobility impaired people.	Planning-Economic	-Reduces car usage -Reduces congestion -Reduces travel times -Reduces emissions -Promotes sustainable modes -Improves road security -Improves habitability -Generates income -Improves productivity	- Air Pollution - Green House Gases - Congestion - Road Deaths - Traffic Safety -Opportunity for active mobility - Access to Mobility Service
2	Charges on vehicles kilometres travelled (ITDP, 2012b).	The nature of this policy can be translated into a tax which is related to the distance covered by private automobiles.	Economic	-Reduces car usage -Reduces congestion -Reduces emissions -Promotes sustainable modes -Improves road security -Promotes economic efficiency -Reduces energy consumption	- Air Pollution - Green House Gases - Congestion - Road Deaths - Traffic Safety - Energy Efficiency -Opportunity for active mobility - Access to Mobility Service
3	Fuel taxes based on environmental parameters (Litman, 2011b).	The purchase of Fossil fuel-based vehicles will result in the application of certain taxes based on environmental parameters.	Economic	-Reduces car usage -Reduces congestion -Reduces emissions -Promotes sustainable modes -Improves road security -Generates income -Promotes the shift to more efficient vehicles	- Air Pollution - Green House Gases - Congestion - Road Deaths - Traffic Safety - Energy Efficiency -Opportunity for active mobility - Access to Mobility Service

led to ranking these policies according to their total impact on SUMI-influenced initiatives.

5.1. Key messages for SUMIs and their interrelations

The most influential indicators are the ones placed in sector 1 of Fig. 4 since they determine the system's behaviour. In this sector we have identified the indicators that are related to public transport (affordability of public transport, multimodal integration and access to mobility services) which, in general, according to literature (e.g., Alyavina et al., 2020; Attard and Hall, 2003; Kinsella and Caulfield, 2011) is the backbone of sustainable mobility, enabling people to cover longer distances and compete against private automobiles. The last SUMI located in this sector is the energy efficiency indicator that affects

Table 7
Strategies for parking and urban planning.

ID	Public policies	Policy definition	Policy Nature	Positive Effects	Interlinked SUMIs
Parking Strategies					
1	Parking meters (ITDP, 2012b).	The installation of specific apparatus on public roads that are capable of regulating the usage of public spaces of a city for the parking of vehicles.	Economic	-Reduces car usage -Reduces congestion -Reduces travel times -Reduces emissions -Promotes sustainable modes -Improves road security -Improves habitability -Improves public space -Generates income -Increases the availability of parking places	- Air Pollution - Green House Gases - Congestion - Noise - Traffic Safety - Road Deaths - Access to Mobility Service -Opportunity for active Mobility
2	Parking requirements in constructions and business (ITDP, 2012b; Litman, 2011c).	The establishment of building regulations concerning minimum parking places requirements in accordance with the type of construction. These requirements, unintentionally, may encourage the utilization of private automobiles through the proportion of parking places.	Economic	-Reduces car usage -Reduces congestion -Promotes sustainable modes -Improves habitability -Improves public space -Generates income -Increases the availability of parking places -Promotes efficient land-use -Reduces construction cost -Promotes real estate development	- Air Pollution - Green House Gases - Congestion - Noise - Traffic Safety - Road Deaths - Access to Mobility Service -Opportunity for active Mobility
Strategies Focusing on Urban Planning					
ID	**Public Policies**	**Policy definition**	**Policy Nature**	**Positive Effects**	**Interlinked SUMIs**
1	Transit oriented development (Sohoni et al., 2017).	Transit-oriented development (TOD) is an urban planning model that aims to establish neighbourhoods close to public transportation systems. A TOD, in general, is characterized by mixed land uses and high density and has as its backbone a bus, BRT or subway station.	Planning	-Reduces car usage -Reduces congestion -Reduces emissions -Promotes sustainable modes -Promotes efficient land-use -Improves road security -Improves habitability -Improves public space -Promotes local economic development -Promotes urban renovation	- Air Pollution - Green House Gases - Congestion - Road Deaths - Noise - Traffic Safety - Access to Mobility Service -Opportunity for active mobility - Energy Efficiency - Affordability of PT -Accessibility to PT for the mobility impaired people - Satisfaction of PT - Multimodal Integration
2	Transit Pacification (ITDP, 2012b).	Transit pacification can be defined as a set of urban planning approaches oriented towards the reduction of volume and speed of vehicles within a particular region of interest.	Regulation-Planning	-Promotes sustainable modes -Promotes efficient land-use -Improves road security -Improves habitability -Improves public space -Improves the amenity value of the area	- Air Pollution - Green House Gases - Congestion - Road Deaths - Noise - Traffic Safety
3	Car-free planning (ITDP, 2012b).	Car-free planning incorporates the design of specific regions so that to assist the utilization of active mobility and therefore reduce the extensive cars usage	Regulation-Planning	-Reduces car usage -Reduces congestion -Reduces emissions. -Promotes sustainable	- Air Pollution - Green House Gases - Congestion - Road Deaths

(continued on next page)

Table 7 (*continued*)

Parking Strategies ID	Public policies	Policy definition	Policy Nature	Positive Effects	Interlinked SUMIs
				modes -Promotes efficient land-use -Improves road security -Improves habitability -Improves public space -Improves urban image	- Noise - Traffic Safety - Access to Mobility Service -Opportunity for active mobility - Energy Efficiency - Affordability of PT

climate change (i.e., energy inefficiency has negative effects to environment). The concept of energy efficiency for transport (Brand et al., 2019) can be integrated with the public transport indicators by actively promoting the implementation of electromobility approaches in the public transport sector; for instance, the purchase of electric (and hybrid) buses to enhance the public transport services within a geographic region. This is in line with relevant literature (Kühne, 2010; Morton et al., 2018).

In sector 2 (Fig. 4) we see the indicators that are extremely influential and dependent at the same time and therefore are, by nature, factors of instability. This is the indicator of congestion, the reduction of which, within a sustainable mobility paradigm elevates liveability and interaction with urban surroundings (Mahmoudi et al., 2015; Rossi et al., 2020; Shi et al., 2018).

The third sector (Fig. 4) includes those indicators that are mainly characterised by high degrees of dependence. However, the two indicators found there (i.e., opportunity for active mobility and traffic safety) are also very close to becoming pivotal indicators (be part of sector 2) and should be treated accordingly. For example, through the enhancement of public transport we can promote multimodal integration among public transport and active modes, while via the strengthening of traffic safety we can help people feel safe and comfortable. This could lead travellers to use more in a daily basis bikes, walk more or do the right mix of public transport and non-motorised mobility. The rest of the indicators shown in this sector are greenhouse gases, air pollution, noise, satisfaction with public transport services and road deaths that could be affected positively by the promotion of sustainable transport modes and especially through the promotion of high-quality public transportation; a finding in line with many studies (e.g., Attard, 2012; Banister and Marshall, 2000). Hence, they could be treated and incorporated in mobility management strategy portfolios along with the ones qualified as “critical” if we want to enhance their effectiveness.

In the last sector (sector 4 in Fig. 4) we observe one of the most considered indicators, i.e., accessibility to public transport for the mobility impaired people, that is close to being a highly dependent indicator due to its high correlation with public transport indicators such as multimodal integration, access to mobility service, affordability of public transport for the poorest and energy efficiency. Therefore, the factor of accessible public transport for mobility impaired people should be prioritised. Consequently, the majority of public transport services should be equipped with adequate accessibility-enhancing infrastructure that will provide truly accessible services and mitigate phenomena of social isolation. This is in line with the recommendations of Church et al. (2000) and Lucas (2012), concerning the relationship between public transport and social exclusion.

5.2. Policy recommendations based on our analysis in order of importance

Based on the MICMAC analysis, this research goes beyond a simple demonstration of the results through proposing some critical policy recommendations. Specifically, Table 5-Table 8 show the results of a thematic narrative literature review (columns 2–4) complemented by the results of our MICMAC discussions (last two columns) concerning the sustainable transport strategies, their policy instruments and the impacts-benefits resulting by their implementations. Each one of the expected impacts was actively interlinked/matched, by the experts (through the structural analysis method), with the SUMIs that have been organised in order of importance. Thus, we can categorise the existing strategies hierarchically in accordance with the benefits generated by their respective SUMIs. In essence, the more SUMIs a public policy-strategy matches, the more effective it can be in delivering positive impacts in more ways.

Hence, the most important group of strategies are the ones about urban design and the most important of them is the Transit Oriented Development (TOD) that influences all the established SUMIs, followed by the transit pacification approach that also tackles the majority of the discussed indicators. TOD is a holistic tool that may indeed facilitate the transition to more liveable futures via its ability to link effectively transport investment with land use planning and decision-making allowing cities to be more accessible, resilient and car-independent (Knowles, 2012; Knowles et al., 2020).

The next group of strategies in terms of importance refers to those around alternative transport modes (i.e., measures for enhancing public transport and non-motorised mobility). For complete door-to-door solutions given that not all pedestrians and cyclists can cover long distances, it is necessary to emphasise strategies promoting public transport usage (Mugion et al., 2018). Among this kind of strategies, the Bus Rapid Transit (BRT) approach (as per Nikitas and Karlsson, 2015) stands out along with the establishment of public transit systems, i.e., suburban train, metro and tram (Knowles and Ferbrache, 2016) and the establishment of exclusive public transport lanes as they are interlinked with all the system’s influential indicators. Nevertheless, BRT approaches are favoured because of lower implementation costs in comparison to rail-based mass-transit systems. Among the active mobility policies, the approach that better covers the considered indicators is the generation of bike lanes (Hull and O’Holleran, 2014; Márquez et al., 2021) followed by the promotion of public bicycle systems (Bakogiannis et al., 2019; Maas et al., 2021; Nikitas et al., 2016; Ricci, 2015) and the creation of walkable neighbourhoods (Nikitas et al., 2019; Potoglou and Arslangulova, 2017).

The next group of strategies in terms of significance is the one looking at parking supply, as this can control a city’s fleet of privately owned cars and as an extent the negative externalities associated to excessive automobile use. More specifically, two key approaches worth prioritising are parking charges (Rye and Ison, 2005; Simićević et al., 2013) and the establishment of minimum parking requirements in houses and businesses (Ison et al., 2007; Thigpen, 2018).

A sustainable mobility system does not necessarily aim to completely “ban” cars, but it does seek to impose some barriers to their excessive usage. Simultaneously it should offer transport alternatives that will help people to cover their everyday mobility needs without having

Table 8
Strategies for efficient mobility and alternatives to automobile usage.

ID	Public policies	Policy definition	Policy Nature	Positive Effects	Interlinked SUMIs
Strategies Focusing on Public Transport					
1	Exclusive lanes for public transport (He et al., 2021; Wright and Hook, 2007).	This type of policy prioritizes the use of public transport. Exclusive public transport lanes are parts of the road which are intended to be used only by buses-BRT systems.	Planning	-Reduces travel times -Improves quality of public transport -Improves reliability and the efficiency of public transport	- Congestion - Satisfaction of PT - Air Pollution - Greenhouse Gases
2	Bus Rapid Transit (BRT) (Wright and Hook, 2007).	BRT is a mass transportation system which is designed to have better capacity and reliability than its ordinary bus counterpart. In general, BRT systems include exclusive lanes for public transport that prioritize their flow at where buses may interact with other motorised traffic. BRT systems are intended to provide similar quality of service as the subway or light rail, but with lower construction costs.	Planning	-Reduces travel times -Improves quality of public transport -Reduces car usage -Reduces congestion -Reduces emissions -Promotes sustainable modes -Improves accessibility -Improves the image of public transport	- Access to Mobility Service - Accessibility of PT - Road Deaths - Traffic Safety - Multimodal Integration -Opportunity for active Mobility
3	Establishment of other massive systems, such as suburban train, metro, tram (Litman, 2012a).	The enrichment of public transportation services via the expansion of public transport systems.	Planning	-Reduces travel times -Improves reliability and the efficiency of public transport -Reduces car usage -Reduces emissions -Promotes sustainable modes -Improves accessibility -Improves the image of public transport -Improves road security -Improves productivity and generates job opportunities	
Strategies Focusing on Bicycles and Pedestrians					
ID	**Public Policies**	**Policy definition**	**Policy Nature**	**Positive Effects**	**Interlinked SUMIs**
1	Public bicycle system (ITDP, 2012b).	The promotion of bike sharing approaches so that to strengthen non-motorised mobility patterns.	Planning	-Reduces travel times -Promotes sustainable modes -Promotes efficient land-use -Improves public space -Promotes multimodality -Enhances the social identity of the city-social cohesion	- Congestion - Air Pollution - Green House Gases -Opportunity for Active Mobility. - Multimodal Integration - Energy Efficiency
2	Establishment of bike lanes (ITDP, 2012b).	The establishment of bike lanes in order to strengthen safe non-motorised mobility patterns.	Planning	-Reduces travel times -Promotes sustainable modes -Improves public space -Reduces emissions -Reduces car usage -Improves road security -Reduces transportation's cost	- Congestion - Air Pollution - Green House Gases -Opportunity for Active Mobility - Energy Efficiency - Road Deaths-Traffic Safety
3	Generation of walkable spaces (Litman, 2011d)	The establishment of pedestrian-friendly neighbourhoods via the protection of residential environment and the enhancement of the attractiveness of public space.	Planning	-Reduces travel times -Promotes sustainable modes -Improves public space -Enhances the social identity of the city-social cohesion -Reduces emissions -Improves accessibility	- Congestion - Air Pollution - Green House Gases -Opportunity for Active Mobility - Energy Efficiency - Accessibility of PT

private cars as a mono-solution but as another (hopefully secondary) option. For that reason, within the sustainable mobility's framework strategies should be those associated with vehicles movement, followed by the strategies about efficient automobile usage and strategies focused on vehicles ownership. This recommendation is in line with key literature findings (e.g., Kim et al., 2019; Namazu and Dowlatabadi, 2018; Nikitas et al., 2011; Tsigdinos et al., 2022).

The last group of strategies is the one associated to no-mobility that tries to tackle the negative externalities of transport activities via the reduction of actual travel. These strategies are strongly related to technological innovations, wireless connectivity and teleworking schemes that may allow people to work remotely from home (Mouratidis and Papagiannakis, 2021). The most important approach, according to our work, is the one related to the establishment of alternative (more flexible) work schedules that not only tackle many negative transport externalities but also encourage the strategies of car-sharing and ride-sharing (Ferrero et al., 2018). The approach of telecommuting/teleworking (Mouratidis and Peters, 2022) is also gaining traction as it substitutes travel altogether. The recent COVID-19 pandemic has shown the high potential of this intervention in reducing trips in general and car trips particularly (Politis et al., 2021b).

6. Conclusions

Nowadays, SUMPs constitute the gold standard in catering for sustainable transport in the city level. SUMPs are powerful tools designed to help cities reduce the environmental, economic, and social impacts generated by fragmented mobility systems that prioritise the use of private automobiles over people. Developing these plans requires from decision-makers to understand the complexities of mobility planning and the value of evaluating measures systematically. Only by a holistic approach that packages transport and land use planning together, the mobility of cities can be improved.

The process of drawing up SUMPs must necessarily include active participation of the local population, socialisation campaigns, continuous monitoring and evaluation (Kyriakidis et al., 2023). It is also important to note that schemes derived by SUMPs should not only have good intentions and be visionary, but they need to be realistic and tied to the necessary financing so that can be actually implemented in full (Chatziioannou et al., 2020a). Failing to consider these factors implies a loss of public resources and loss of an opportunity to change urban mobility.

Within this framework, our paper proposed a systematic assessment that could inform policy adoption for transport planning. We evaluated advances that emerge from new and tested mobility strategies, policies and schemes and linked them with relevant SUMIs that we identified and cross-checked with our expert participants. This matching process allowed us to rank these policies in order of their importance (i.e., the more SUMIs a policy interrelates with, the better and more important it may be for a city). Their combination according to the capabilities and characteristics of the city host can support the transition to a sustainable mobility paradigm. Their promotion should be branded as an intervention genuinely linked with SUMIs. The lessons learnt from our work could hopefully inform and eventually help cities in Europe (and beyond) in achieving goals that will allow them to be less car dependent, more accessible and genuinely liveable environments. We specifically paid attention to European cities because SUMIs are a European initiative, but these lessons could be generalisable to some degree for some international cities with similar characteristics.

All the above-mentioned strategies and public policies should be part of a comprehensive and holistic long-term plan of mobility rather than partially implemented and fragmented counter measures. However, cooperation and participation between the different actors involved within the urban planning process (i.e., transport and urban design authorities, planning and public policy agents, and common people) is essential when it comes to the adoption of integrated and coherent SUMPs.

Despite the depth and breadth of our results, we need to acknowledge that our study has some limitations. The sample size, even though is sufficient for providing valid results according to MICMAC guidelines, could have been bigger. Moreover, the adoption of only two limited values (“1″ and “0”), aiming to keep the consulting process as simple as possible, could be considered as another limitation. It would be intriguing to see, as subject of future research, how the results of the variables categorisation would have been, if we would have considered the intensity of the direct relations within the matrix.

Future research should also aim to combine structural analysis with quantitative studies with the aim to assign weights to the hierarchically organised SUMIs we developed. This is something that the present work did not facilitate, because of its exploratory and primarily qualitative focus. This would improve the process of evaluating mobility plans against strategic targets and support the creation of a homogeneous assessment framework. This could take then the form of a synthesised index that considers jointly public attitudes that reflect and affect the urban mobility planning process and the effectiveness of sustainable mobility measures.

CRediT authorship contribution statement

Ioannis Chatziioannou: Methodology, Writing – original draft, Writing – review & editing. **Alexandros Nikitas:** Methodology, Writing – original draft, Writing – review & editing. **Panagiotis G. Tzouras:** Writing – original draft, Writing – review & editing. **Efthimios Bakogiannis:** Writing – original draft, Writing – review & editing. **Luis Alvarez-Icaza:** Methodology, Writing – original draft, Writing – review & editing. **Luis Chias-Becerril:** Methodology, Writing – original draft, Writing – review & editing. **Christos Karolemeas:** Writing – original draft, Writing – review & editing. **Stefanos Tsigdinos:** Writing – original draft, Writing – review & editing. **Pontus Wallgren:** Methodology, Writing – original draft, Writing – review & editing. **Oskar Rexfelt:** Methodology, Writing – original draft, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The data that has been used is confidential.

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