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# Use of the Sustainable Mobility Efficiency Index (SMEI) for Enhancing the Sustainable Urban Mobility in Greek Cities

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**Abstract:** Since 2013, the European cities have been encouraged to develop local Sustainable Urban Mobility Plans (SUMPs) according to the specific procedure that was launched by the Directorate-General for Mobility and Transport (DG Move) and updated in 2019. One of the most critical steps in this 12-step procedure is the assessment—with specific criteria—of all the alternative measures and infrastructure, which will be optimally combined, in order to better satisfy the problems and the achieve the vision of each area. The aim of the current work is to present the development and implementation of a methodological framework based on the use of multicriteria analysis. The framework targets the capturing of opinions of the relevant local experts in order to evaluate alternative sustainable mobility measures, and also prioritize them using the Sustainable Mobility Efficiency Index (SMEI).

**Keywords:** sustainable urban mobility planning; measures assessment; multicriteria analysis; Sustainable Mobility Index

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## 1. Introduction

Urban transport planning in a more sustainable and human-centric philosophy is an integral part of the overall urban planning processes currently taking place in modern cities. The main idea is based on the depreciation of the urban/network space, which is given to private vehicles, the construction of infrastructure for public transport, walking, biking, and the development of new transport schemes such as bike or car-sharing systems. This new method of urban journeys will significantly influence many aspects of the quality of life in cities, such as residents' health, safety, economic and development opportunities, and conditions of work and leisure.

The first European strategy towards a more sustainable transport planning was launched in 1992, when the first version of the EU White Paper was released, which was focused on coherence and fair modal competition (COM(1992) 0494) [1]. The second version was released in 2001 (COM(2001) 370 final), promoting regulated competition, modal integration, multimodality and bottleneck elimination, user- and real cost-focused transport policy, alternative fuels and transport globalization, among other strategic and legislative documents [2].

In 2007, the Green Paper on Urban Mobility (COM(2007) 551 final) was adopted, aimed at addressing challenges towards the achievement of free-flowing and green cities, as well as smart, accessible, safe, and secure public transport, with a shift in urban mobility culture being the overarching objective [3].

The 2009 Action Plan on Urban Mobility (COM(2009) 490 final) operationalized the Urban Mobility Policy through twenty actions in five thematic areas that covered policy integration, citizen-focused and environmentally-oriented policies, funding, knowledge dissemination, capacity building, and optimization through institutional, management and technological innovation [4].

In 2010, the Europe 2020 strategy (COM(2010) 2020) was introduced, aiming at three priority areas for Europe, namely, smart, sustainable, and inclusive growth, considering the economic and social impacts of the financial crisis. The strategy was translated into quantifiable targets directly or indirectly related to the areas of innovation, education, digital society, climate, energy, mobility, competitiveness, employment, skills, poverty reduction, and governance. Thus, one understands that mobility is a crucial component for the success of Europe's transformative path, while urban mobility, in particular, influences strategy implementation predominantly in the areas mentioned above [5].

The significance of transport and mobility and the future thereof in the European context was addressed in a more detailed manner in the 2011 White Paper on Transport Policy (COM(2011) 144 final) [6]. It was focused on the realization of a European Transport future structured upon a competitive, economically, socially, and environmentally sustainable, as well as integrated, safe, secure, and resource-efficient Single European Transport Area, where innovation takes place in many levels, e.g., technology, regulation, governance, funding, infrastructure, etc. This vision was expressed through a set of forty (40) relevant initiatives that constitute the backbone of EU Transport Policy and are the main policy instruments that will materialize goals and strategies into actions, results, and impacts, until the year 2050. Although urban mobility is addressed explicitly in the form of Integrated urban mobility (Urban Mobility Plans, urban road user charging, and near-zero-emission urban logistics), the majority of the remainder initiatives interact physically and functionally with the urban environment and the urban mobility system.

The accompanying Impact Assessment (SEC(2011) 358 final) highlighted the unsustainability of the transportation system, primarily in terms of greenhouse gas (GHG) emissions, oil dependency, congestion, internalization of social costs, and correspondence to mobility needs and aspirations of people and businesses [7].

Thus, as far as urban mobility is concerned, the role of Sustainable Urban Mobility Plans, charging schemes, and urban logistics are pivotal for developing sustainable urban mobility systems throughout the EU. At the same time, the international dimension should also be taken into consideration.

The first version of the Guidelines for Sustainable Urban Mobility Planning was published in late 2013 by DG Move [8]. One hundred and sixty-eight planning practitioners and other experts from all over Europe contributed to a comprehensive consultation to define this new planning concept. In parallel, the European Commission systematically developed its urban mobility policy and published its Urban Mobility Package that included a definition of the idea of "Sustainable Urban Mobility Plans" [9].

Six years later, significant new developments in many areas of urban mobility took place, such as new technologies, driverless electric vehicles, new business models providing "Mobility as a Service", shared mobility, and cycling. As a result, an update of the original SUMP guidelines was published at the end of 2019 [10].

The updated SUMP guidelines offer concrete suggestions on how to apply the SUMP concept and prepare an urban mobility strategy that builds on a clear vision for the sustainable development of a metropolitan area. This process of developing and implementing a SUMP is broken down into four main phases and 12 main steps:

Phase 1: Preparation and Analysis
- Step 1: Set up working structure;
- Step 2: Determine the planning framework;
- Step 3: Analyze the mobility situation;

Phase 2: Strategy Development
- Step 4: Build and jointly assess scenarios;
- Step 5: Develop vision and strategy with stakeholders;
- Step 6: Set targets and indicators;

Phase 3: Measure Planning
- Step 7: Select measure packages with stakeholders;

Step 8: Agree on actions and responsibilities;
Step 9: Prepare for adoption and financing;

Phase 4: Implementation and monitoring

Step 10: Manage implementation;
Step 11: Monitor, adapt, and communicate;
Step 12: Review and learn lessons.

The concept of sustainable urban mobility planning, as defined in the Urban Mobility Package, is based on eight commonly accepted guiding principles: the planning addresses the needs of all the urban functional area and is based on the close cooperation across institutional boundaries together with the active involvement of the citizens.

The planning should also assess the urban transportation system's current and future performance, creating a clear vision for the future and developing all transport modes in an integrated manner. Finally, it should incorporate very detailed monitoring and evaluation plans, also assuring the quality of its implementation.

It becomes clear that the methodology of sustainable urban mobility planning is based on an approach according to which the future problems of the city and the solutions to the issues are considered from a more significant number of aspects, so that experts from the field of transportation engineering become a necessary part of a broader interdisciplinary team. In this team, a substantial role in the decision-making process is given to professionals from other fields and the public.

There are many decisions and different parameters during the sustainable urban mobility planning process, which should be taken into account. The selected strategy that will be followed to serve the city's vision, the targets of the city's future development, the chosen measures, and infrastructure that need to be built to achieve these targets but are also feasible to be realized in the specified time limits all must be considered.

There are many mobility schemes and measures that can be used for boosting sustainable mobility in a city. The challenge of the stakeholders is to select those most appropriate for motivating their citizens to reduce the use of private cars towards more environmentally friendly modes of travel. The introduction of shared bike systems and e-vehicles, the redesign of public transport systems, the purchase of an e-fleet and upgraded facilities for park and ride, and the use of Mobility As A Service (MaaS) for providing integrated information and ticketing are some of the most effective alternatives. Especially regarding the shared mobility schemes, their contribution to increased sustainability or urban mobility is two-fold; they are an active mode of transport, and a shared one. The external benefits of bicycle use have been consistently found to be heavily increased compared to the private car, and they extend to health benefits, noise reduction, increased safety, and reduced environmental pollutants [11]. Additionally, some studies have showed that according to the citizens views, the use of bike sharing systems is the safer option compared to using a taxi and, especially compared to public transport usage in pandemic crises such as coronavirus disease 2019 (COVID-19) [12].

In these circumstances where the optimum solutions should be selected, the cost–benefit analysis (CBA) method is used for evaluating, on the one hand, the benefit from implementing specific infrastructure/measures, and on the other hand, the specific limitations (social, environmental, etc.). CBA is primarily used due to the impossibility of adequately valorizing these measures/infrastructures in terms of their specific impact on the environment or community by calculating monetary values [10].

To improve the decision-making process in such complicated circumstances, it is essential to apply new tools to raise the level of transparency and objectivity of the solution selection process.

This work aims to formulate and implement a methodological framework for ranking sustainable mobility measures using a detailed index to improve decision-making in the sustainable urban mobility planning process. The methodology used for formulating the current framework is presented in the next section, and the results of its implementation in the third. The paper ends with the final conclusions.

## 2. Materials and Methods

### *2.1. The SMEI Methodological Framework*

Given that the transport infrastructure planning problems can be characterized as structured problems, they are suitable for the application of MCDA (multicriteria decision analysis) methods. The MCDA methodology is considered the most appropriate method used by many cities during a series of workshops to evaluate the different measures and select the most significant once. Analyses of papers from relevant scientific bases (Figure 1) showed that MCDA methods have been used as a decision-making tool in the process of planning, design, maintenance, and reconstruction of transport infrastructure and measures in urban areas [13]. This analysis shows that, regardless of the type of issue considered, the analytic hierarchy process (AHP) method is the most frequently used compared to other MCDA methods [13–34]. More often used MCDA methods are the PROMETHEE, SAW, and then ELECTRE, ANP, REGIME, MAUT, and TOPSIS [35].

| Phase | Type of infrastructure/problem description | Applied methods in making decisions about transport infrastructure | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | AHP | ANP | ELECTRE | PROMETHEE | REGIME | MAVT | SAW | TOPSIS | MCA&GIS | MCA&CBA | DEX |
| PLANNING | All infrastructure | | | X | | | | X | X | X | | |
| | Transport infrastructure - in general | X | | X | X | | | | | | | |
| | Transport infrustructure in urban areas/selection of a railway line | X | | | | | | | | | | |
| | Transport infrastructure in urban areas/selection of city bypass route/investment project appraisal | | | | | | | | | | | X |
| | Transport infrastructure in urban areas/selection of a new metro line route-EU funded project | | | | | | X | | | | | |
| | Transport infrustructure in urban areas/bicycle facility planning | | | | | | | X | | X | | |
| | Transport infrastructure in urban areas/GPF location selection | X | | | | | | | | | | |
| | Transport infrastructure in urban areas/selection of a location for a port for nautical tourism | | | | X | | | | | | | |
| | Transport infrastructure in urban areas/selection of an project alternative for improvement of road infrastructure | | | | | | | X | | | | |
| | Transport infrastructure in urban areas/selection of an optimum transport system | X | | | | | | | | | | |
| | Transport infrastructure in urban areas/transport planning on neighbourhood level | X | X | | | X | | | | | X | |
| | Transport infrastructure in urban areas/selection of a GPF location and definition of the GF investment strategy | X | | | X | | | | | | | |
| | Transport infrastructure in urban areas/selection of an urban railway transport project | X | | | | | | | | | | |
| DESIGN | Transport infrastructure design/in-general | X | | X | X | | | | | | | |
| | Transport infrastructure in urban areas/selection of a GPF type on an already defined location | X | | | | | | | | | | |
| MAINTENANCE/ RECONSTRUCTION | Transport infrastructure in urban areas/selection of an alternative for road infrastructure and crossing with railway infrastructure-transport investment | X | | | | | | | | | | |
| | Transport infrastructure in urban areas/selection of optimum pedestrian crossing on an already defined location | X | | | | | | | | | | |
| | Transport infrastructure in urban areas/road maintenance management | X | | | X | | | | | | | |
| | Transport infrastructure in urban areas/rehabilitation and maintenance of rads | X | | | | | | | | | | |

**Figure 1.** Application of multicriteria decision analysis (MCDA) methods in different phases of transportation projects of urban areas [13].

Thomas L. Saaty developed the AHP method in the 1970s. The application of AHP has been intensified over the past decade in decision-making processes relating to transport infrastructure. The advantage of the AHP method lies in the possibility of selecting the best solution by setting the hierarchy of goals, criteria, and alternative solutions and in enabling the decision-making based on collaboration between different stakeholders (professionals and the public). However, in the planning phase, for selecting an appropriate solution, the use of the AHP, PROMETHEE, or ELECTRE methods is suggested [36–39].

The PROMETHEE (Preference Ranking Organization METHod for Enrichment of Evaluations) method, which is used for the current work, is based on mathematics and sociology and was developed at the beginning of the 1980s. Rather than pointing out a "right" decision, the PROMETHEE method helps decision-makers find the alternative that best suits their goal and their understanding of the problem. It provides a comprehensive and rational framework for structuring a decision problem, identifying and quantifying its conflicts and synergies, clusters actions, and highlights the main alternatives and the structured reasoning.

PROMETHEE results are presented by means of the total cost–function value (Phi value) obtained for each action and are further assessed using PROMETHEE tables and charts. PROMETHEE prioritizes the actions/interventions from the highest to the lowest Phi value in its scaled form in the range from −1 (worst solutions) to +1 (best solutions), meaning that actions with positive Phi could be considered more acceptable.

The above-mentioned MCDA methods also adhere to the requirements of the Sustainable Urban Mobility Plans development. The authors of the SUMP specifications propose to present the list of measures and infrastructure to a group of experts (stakeholders or even citizens groups) in order to rate each measure individually. The rating should be performed considering their realistic and timely implementation with the given resources (pre-feasibility check), ensuring that all costs and benefits—not just those that can be easily measured or valued—are considered. The results of this procedure are used to compare and prioritize measures. For a more qualified standard, it can be useful to weigh experts' ratings depending on their field of expertise (e.g., environmental experts have a higher weighting in the air quality rating, financial experts in the cost rating, etc.).

The evaluation and ranking of the alternative measures consist the main target of the specific work and is based on a six-step methodology for calculating the Sustainable Mobility Efficiency Index (SMEI) for each proposed measure according to the Figure 2 below. The framework is based on the application of PROMETHEE multicriteria analysis and is analytically presented in the next sections [33–37].

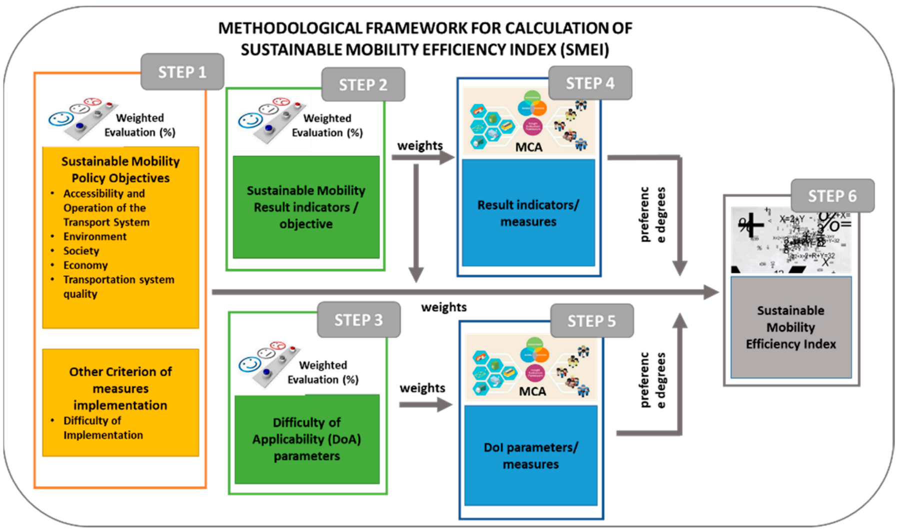


**Figure 2.** Methodological framework for evaluating alternative sustainable mobility measures using Multicriteria Decision Making Analysis.

Each step of the framework is presented analytically in the following sections.

*2.2. Evaluation of Policy Objectives and Result Indicators*

As a first step of the proposed framework, specific weight should be given to each policy objective served by the SUMP implementation. The main objectives that every sump should serve according to the European Platform on Sustainable Urban Mobility Plans (ELTIS) updated SUMP guidelines are the following:

- Accessibility and operation of the transport system;
- Environment;
- Society;
- Economy;
- Transportation system quality.

However, apart from these objectives, a crucial criterion for the successful implementation of the SUMP measures is the difficulty of applicability regarding the institutional interactions, the SUMP owner's authorization to implement these measures, legal barriers, challenges for finding funding opportunities, etc. For this reason, weight should also be given to the specific criterion so-called Difficulty of Applicability (Institutional Interactions/Funding opportunities).

For each one of the above objectives, specific result indicators have been determined. Thus, as a second step, the weight of each result indicator should be evaluated, answering the question: "how much does each indicator contribute to bringing the city closer to its specific vision of sustainable mobility and development?" These indicators per objective are presented in Table 1. The indicators were formulated according to the sustainable mobility impact methodologies that were used in relevant EU projects such as SUMI, SUMP-UP, MO-MENTUM and the re-sent report of the project "SUMI-sustainable mobility indicators" of DG MOVE.

**Table 1.** Result indicators per objective.

| Objectives | Result Indicators |
|---|---|
| Accessibility | Increase in the number of kilometers travelled by bicycle |
| | Increase in the number of kilometers travelled by public transport |
| | Increase in pedestrian kilometers |
| | Reduction in time between specific Origin-Destination pairs travelled on foot. |
| | Reduction in the time between specific Origin-Destination pairs travelled by bicycle. |
| | Reduction in the average walking distance to/from bus stops for specific Origin-Destination pairs. |
| Society | Reduction (%) in dead and seriously injured in road accidents within the urban network |
| | Reduction in social exclusion due to low accessibility to transport services of people with mobility problems |
| Environment | Reduction (%) in $CO_2$ and $NO_x$ emissions caused by traffic |
| | Reduction (%) in noise emissions caused by traffic |
| Economy | Increase in new jobs |
| | Contribution of measures to the various economic sectors of the city (tourism, entrepreneurship, etc.) |
| Transportation system quality | Upgrading the quality of the public transport system |
| | Upgrading the offered quality of bicycle infrastructure |
| | Upgrading the quality of infrastructure offered for walking. |

The criterion "difficulty of applicability" also followed the same approach. Five important parameters were determined (Table 2), and specific weights were allocated to each of them.

**Table 2.** Parameters of the criterion "difficulty of applicability".

| Criterion | Parameters |
|---|---|
| Difficulty of applicability/Interactions | The institutional responsibility for the implementation of the measures exclusively belongs to the municipality or there is a need for cooperation with other bodies. |
| | Interaction of the measure with other measures or infrastructure that needs to be implemented. |
| | Legal and institutional barriers that need to be overcome for implementing the current measure. |
| | Total investment cost. |
| | Opportunities to include the project in European, national, or regional funding schemes, or capability to be financed by own resources. |

### *2.3. Evaluation and Ranking of Sustainable Mobility Measures Effect*

The third step of the methodology regards evaluating the intensity with which each measure affects the result indicators of the policy objectives.

In contrast, the fourth step follows the evaluation of the power with which each measure's implementation is being affected by the criterion "difficulty of applicability" parameters. For the pilot implementation of the methodology, and based on the selection of measures that so far seem to be mainly proposed and adopted by the Greek authorities who implement their SUMPS, specific measures were selected for evaluation, as presented below:

1. Development of a shared system of electric and conventional bicycles as well as small-capacity electric cars.
2. Redesign of the existing public transport system.
3. Introduction of an e-bus line by the operator of the existing public transport system.
4. Development of a new high-frequency municipal e-bus line.
5. Conversion of the city's central commercial axis to a 3 km pedestrian walkway with open spaces for the citizens and infrastructure for biking and recreation areas.
6. Conversion of the central commercial axis into a light traffic road, with exclusive access to buses, taxis, electric vehicles, bicycles, and many open spaces for pedestrians.
7. Conversion of a municipal open space to a central bioclimatic park with recreation areas, cultivation, thematic parks, etc.
8. Development of an advanced technology traffic and parking monitoring and management center offering real-time traffic information and routing services to the citizens (via web or mobile app).
9. Implementation of infrastructure and the creation of incentives to promote e-mobility. Installation of electric vehicle charging stations in several axes of the city center's urban network and off-road parking stations. Reduced cost of on-road parking.
10. Implementation of infrastructure for enhancing the mobility of people with disabilities.

The fifth step of the methodology regards applying the PROMETHEE multicriteria analysis, which will calculate the multicriteria preference degree of the measures separately, to the policy objectives and the difficulty of applicability parameters.

Finally, the sixth step of the framework combines the PROMETHEE analysis results with the weight given to each objective and criterion to calculate the Sustainable Mobility Efficiency Index (SMEI) for each proposed measure, ranking and prioritizing them.

### 2.4. Collecting the Relative Data

The methodological framework was based on the weights that the experts of sustainable mobility planning gave to specific parameters and their influence in successfully implementing the mobility solutions/measures.

The ten experts who shared their experience were mainly staff from the municipalities' technical departments (7/10) and engineers (3/10) who had worked as external consultants of the municipalities during development of the SUMPs to ensure the successful implementation of them and the achievement of their targets. From the technical staff of municipalities, five had already worked for developing their SUMPs, and were in the process of implementing the proposed infrastructure, while two of them were currently developing their SUMPs.

The questionnaire was formulated after many relevant discussions with the experts regarding specific obstacles and difficulties that they faced during the SUMP development and the knowledge gained during the monitoring phase and the real implementation of the proposed measures.

After the first round of discussions, a first draft version of the questionnaire was developed and sent to the expert group. Considering all the input and comments, the final version was formulated and sent back to the experts. The time given to them was three months, so as to enable discussions of their feedback with all the municipalities' relevant personnel who worked in the different stages of the SUMP implementation.

The main results of each step of the framework are shown in the next section.

## 3. Results

### 3.1. Ranking of the Objectives and Result Indicators

For the initial analysis of the questionnaire results, an Excel database was developed, and all the replies of the questionnaires were imported. The average weights of all the responders were used to rank the importance of the different objectives, the result indicators, and the difficulty of applicability criterion parameters, as presented in the tables and figures below.

Initially, the average weights that were given by the experts with regards to the six main objectives were analyzed and ranked. These results are presented in the following Table 3 and Figure 3.

**Table 3.** Ranking of the sustainable mobility planning objectives according to their importance weight.

| Objectives | Average Weights (%) |
|---|---|
| Accessibility | 26 |
| Environment | 20 |
| Difficulty of applicability/interactions | 15 |
| Society | 14 |
| Transportation system quality | 13 |
| Economy | 12 |

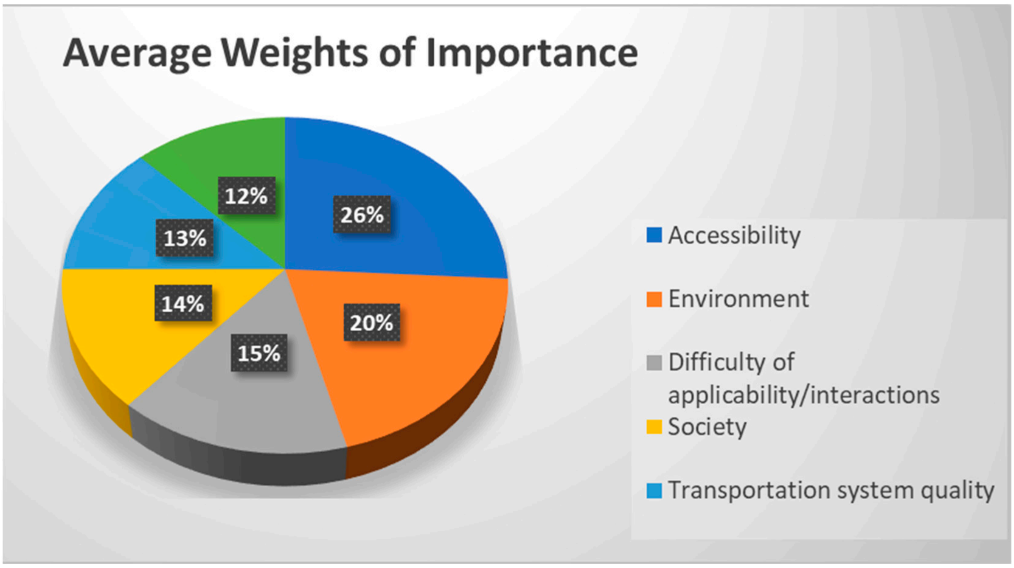


**Figure 3.** Average weights of importance per mobility planning objective.

Then, the average weights of the result indicators, given directly by the experts, were calculated and are presented in Table 4.

**Table 4.** Ranking of the sustainable mobility planning result indicators according to their importance weight.

| Objectives | Result Indicators | Average Weight Given by the Expert Group (1) |
|---|---|---|
| Accessibility | Increase in the number of kilometers travelled by bicycle | 5.91 |
| | Increase in the number of kilometers travelled by public transport | 10.09 |
| | Increase in pedestrian kilometers | 7.45 |
| | Reduction in travel time between specific O–D pairs travelled on foot. | 8.09 |
| | Reduction in the travel time between specific O–D pairs travelled by bicycle. | 4.18 |
| | Reduction in the average walking distance to/from bus stops for specific O–D pairs. | 6.36 |
| Society | Reduction (%) in dead and seriously injured in road accidents within the urban network | 8.36 |
| | Reduction in social exclusion due to low accessibility to transport services of people with mobility problems | 7.45 |
| Environment | Reduction (%) in $CO_2$ and $NO_x$ emissions caused by traffic | 5.64 |
| | Reduction (%) in noise emissions caused by traffic | 5.09 |
| Economy | Increase in new jobs | 4.45 |
| | Contribution of measures to the various economic sectors of the city (tourism, entrepreneurship, etc.) | 5.36 |
| Transportation system quality | Upgrading the quality of the public transport system | 7.00 |
| | Upgrading the offered quality of bicycle infrastructure | 6.91 |
| | Upgrading the quality of infrastructure offered for walking. | 7.64 |

### *3.2. Ranking of the Easiness of Implementation Parameters*

After calculating the objectives and the result indicators, the difficulty of applicability parameters' average weights were also calculated. The values were given by the expert group in each one of the parameters, and are presented in the next Table 5 and

Figure 4. The specific weights were also used in the next steps of the framework during the multicriteria analysis.

**Table 5.** Ranking of the measures' difficulty of application parameters according to their importance weight.

| Difficulty of Applicability Parameters | Average Weights |
|---|---|
| Legal and institutional barriers that need to be solved for implementing the current measure. | 23.64 |
| Interaction of the measure with other measures or infrastructure that needs to be implemented. | 20.91 |
| Opportunities to include the project in European, national, or regional funding schemes or capability to be financed by own resources. | 20.91 |
| Total investment cost. | 17.73 |
| The institutional responsibility for the implementation of the measure exclusively belongs to the municipality or is there a need for cooperation with other bodies. | 16.82 |

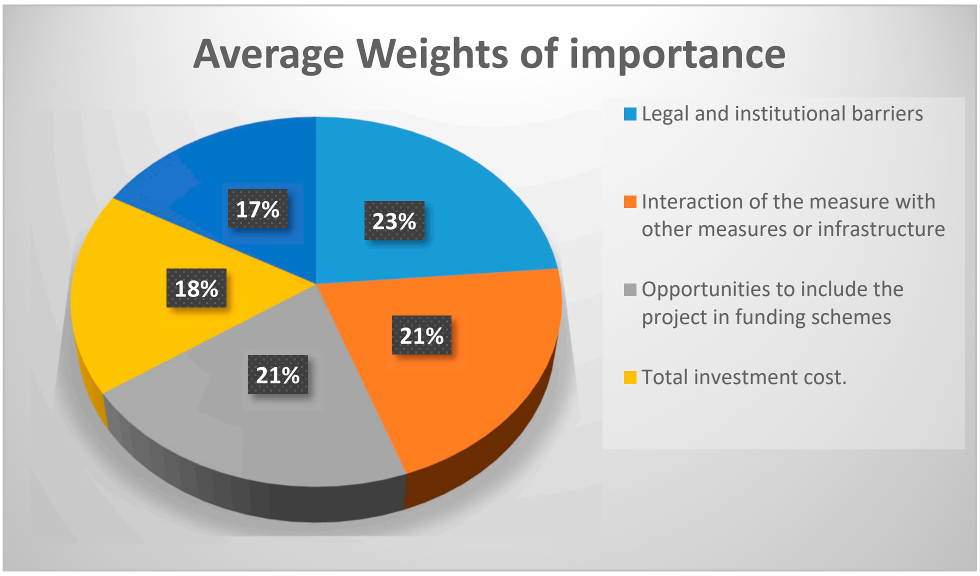


**Figure 4.** Average weights of importance per difficulty of application parameter.

### *3.3. Ranking of the Measures Using Multicriteria Analysis*

In penultimate table of the questionnaire survey, the effect that each measure could bring to the result indicators of the policy objectives was assessed by the experts. The last table, regarding the way that the measures' implementation could be affected by the parameters of the "difficulty of applicability" criterion, was stated. For both cases, the experts were asked to evaluate on a scale (1/low–5/high). These values/weights were imported in the databases that were developed in the PROMETHEE MCDA software.

The weights calculated in the previous chapter (Tables 4 and 5) of the result indicators and the "difficulty of applicability" parameters were also imported. The relative results are presented in Tables 6 and 7.

**Table 6.** Ranking of the measures according to the result indicator preference degrees.

| | Measures | Phi | Phi+ | Phi− |
|---|---|---|---|---|
| 1 | Conversion of central commercial axis of the city to a 3 km pedestrian walkway | 0.2277 | 0.5139 | 0.2862 |
| 2 | Introduction on an e-bus line by the operator of the existing public transport system | 0.1677 | 0.4547 | 0.287 |
| 3 | Conversion of the main commercial axis into a light traffic road | 0.1623 | 0.4907 | 0.3284 |
| 4 | Redesign of the existing public transport system | 0.1487 | 0.4574 | 0.3087 |
| 5 | Development of a new high-frequency municipal e-bus line | 0.1232 | 0.4431 | 0.3199 |
| 6 | Conversion of a municipal open space to a central bioclimatic park | 0.0518 | 0.4346 | 0.3828 |
| 7 | Implementation of infrastructure for enhancing the mobility of people with disabilities | −0.1379 | 0.3448 | 0.4828 |
| 8 | Development of a shared system of electric and conventional bicycles, as well as small-capacity electric cars | −0.1752 | 0.3374 | 0.5126 |
| 9 | Development of a high technology traffic and parking monitoring management center | −0.2187 | 0.3044 | 0.523 |
| 10 | Implementation of infrastructure and creation of incentives to promote e-mobility | −0.3496 | 0.231 | 0.5806 |

**Table 7.** Ranking of the measures according to the "difficulty of applicability" parameters preference degrees.

| | Measures | Phi | Phi+ | Phi− |
|---|---|---|---|---|
| 1 | Implementation of infrastructure and creation of incentives to promote e-mobility | 0.12 | 0.3976 | 0.2777 |
| 2 | Development of a shared system of electric and conventional bicycles as well as small-capacity electric cars | 0.1167 | 0.3802 | 0.2635 |
| 3 | Conversion of a municipal open space to a central bioclimatic park | 0.1027 | 0.3572 | 0.2545 |
| 4 | Conversion of the central commercial axis of the city to a 3 km pedestrian walkway | 0.0665 | 0.3292 | 0.2627 |
| 5 | Development of a high technology traffic and parking monitoring management center | 0.0614 | 0.3416 | 0.2803 |
| 6 | Introduction of an e-bus line by the operator of the existing public transport system | 0.0245 | 0.334 | 0.3096 |
| 7 | Development of a new high-frequency municipal e-bus line | −0.0412 | 0.2941 | 0.3353 |
| 8 | Redesign of the existing public transport system. | −0.1115 | 0.2853 | 0.3968 |
| 9 | Implementation of infrastructure for enhancing the mobility of people with disabilities | −0.1649 | 0.247 | 0.4119 |
| 10 | Conversion of the main commercial axis into a light traffic road | −0.174 | 0.2329 | 0.4069 |

Following the weights that were given by the experts (Table 3), the objectives of a SUMP were weighted as 0.85 and the criterion "difficulty of applicability" as 0.15. The final Sustainable Mobility Efficiency Index was calculated by multiplying the preference degree of measures according to the result indicators Phi(RI) by 0.85, and subtracting the preference degree according to the difficulty of applicability Phi(da) multiplied by 0.15.

$$SMEI = 0.85 \times Phi(RI) - 0.15 \times Phi(da)$$

The results and the final ranking, according to these values, are presented in Table 8 below.

**Table 8.** Comparison of the measures according to their impact of sustainable mobility and difficulty of applicability.

| | Measures | Ranking According to Their Impact to Sustainable Urban Mobility | Difficulty of Applicability Indicator | Sustainable Mobility Efficiency Index (SMEI) | Final Ranking According to SMEI |
|---|---|---|---|---|---|
| 1 | Conversion of central commercial axis of the city to a 3 km pedestrian walkway | 0.2217 | 0.0665 | 0.1552 | 1 |
| 2 | Introduction of an e-bus line by the operator of the existing public transport system | 0.1746 | 0.0245 | 0.1501 | 4 |
| 3 | Conversion of the main commercial axis into a light traffic road | 0.1641 | −0.174 | 0.3381 | 2 |
| 4 | Redesign of the existing public transport system | 0.1568 | −0.1115 | 0.2683 | 3 |
| 5 | Development of a new high-frequency municipal e-bus line | 0.1333 | −0.0412 | 0.1745 | 5 |
| 6 | Conversion of a municipal open space to a central bioclimatic park | 0.0433 | 0.1027 | −0.0594 | 6 |
| 7 | Implementation of infrastructure for enhancing the mobility of people with disabilities | −0.1387 | 0.12 | −0.2587 | 7 |
| 8 | Development of a shared system of electric and conventional bicycles as well as small-capacity electric cars | −0.1794 | 0.1167 | −0.2961 | 8 |
| 9 | Development of a high technology traffic and parking monitoring management center | −0.217 | 0.0614 | −0.2784 | 9 |
| 10 | Implementation of infrastructure and creation of incentives to promote e-mobility | −0.3588 | −0.1649 | −0.1939 | 10 |

## 4. Discussion

Authors should discuss the results and how they can be interpreted from the perspective of previous studies and of the working hypotheses. The findings and their implications should be discussed in the broadest context possible. Future research directions may also be highlighted.

The main scope of the current methodology, as has already been mentioned, was to select the most appropriate measures that should be implemented in a city to upgrade its sustainable mobility and development. Thus, the critical review of the methodology implementation regarding the ranking of the proposed measures and how the stakeholders evaluate them is crucial.

According to the SMEI and the evaluation of the experts' group, the most crucial measure is the conversion of a central commercial axis to a pedestrian walkway. According to Greece's existing experience, this seems to be one of the most popular measures of the cities' planning. Most Greek towns have restructured their central commercial axes to pedestrian roads during the 21st century, giving space to walking and cycling. This practice is well-known and tested. Even though there are specific difficulties and barriers in its implementation, local administrations feel confident in overcoming them. If the axis to be converted to the pedestrian path is very well studied regarding: the influence of this axis on the operation of the rest of the network; the existence of alternative routes of public transport lines that cross this axis; and the access for emergency vehicles, then this measure can be considered as the first step for giving space to people, motivating them to walk and cycle in the city center.

When the study of the network operation as a pedestrian walkway results in difficulties of the neighboring network to serve the traffic and the inhabitants' needs, then the alternative of the light traffic road can be used. This seems to be the second choice of the local administrators for achieving sustainable mobility. Even though the conversion of a central traffic road to a light traffic road demands fewer legal and administrative procedures, it is undoubtedly not such a strong message in favor of shifting to sustainable means of transport.

Sustainable urban mobility planning takes, as a prerequisite, the existence of alternatives to private cars for covering journey demands, and more precisely, the operation of a well-structured and high-quality public transport system. For this reason, local administrators believe that measures targeted to the redesign and the upgrading of the public transport system are the most important aspects of the planning.

As a next step for the upgrade of sustainable mobility, the local administrators chose to implement sustainable parks (bioclimatic areas). The development of open spaces for people, even if it is not an accurate measure of mobility, reinforces sustainable behavior due to the access to a shared place where people can walk, bike, run, and play. The open spaces and parks simulate a city's environment without traffic, noise, and air pollution, giving an excellent example of the town's targets in favor of sustainable mobility and way of life.

The implementation of infrastructure for enhancing the mobility of people with disabilities is a high priority of sustainable mobility planning. The ranking of this measure in the 7/10 position does not decrease its importance. The expert group believed that all the steps mentioned above are essential for achieving accessibility to the urban network and the free movement of people with disabilities. The development of pedestrian or low traffic roads (with a lot of space for walking), the implementation of a high-quality public transport system (including infrastructure for disabled people), and the introduction of open spaces/parks accessible for all also strengthens the accessibility of the city. More relevant infrastructure for people with disabilities is also considered necessary.

Finally, it seems that the Intelligent Transport Systems (ITS) and Intelligent Communication Technologies (ICT) as well as the electromobility infrastructure are not considered as crucial as the other measures for the achievement of sustainability. The experts' priorities mainly focused on the "offering of alternatives" to the citizens to cover the demand for trips by public transport and walking. The next most important aspect seemed to be inclusive mobility and the technology which supported clean private vehicles or monitored the traffic. These latter measures were evaluated as not so important as the others, but were also considered difficult to implement due to their high costs and legal, institutional, or technological barriers.

The final ranking seems to confirm the methodological framework's correctness, because it produced logical results based on European experience and practices.

## 5. Conclusions

Sustainable urban mobility planning is a relatively new concept with high potential for improving low carbon economy policies. Despite many studies, the availability of several reference documents, and a series of European projects and initiatives, only a limited number of cities across Europe have adopted an Sustainable Urban Mobility Plan (SUMP) [16]. This is due to competence, knowledge, technical and normative limits, and low financing by the local administration. Even more problems are encountered in countries such as Greece, where the public's mobility attitude is not in favor of environmentally friendly means of transport.

According to the technical staff of the Greek public authorities responsible for implementing the new cooperative planning philosophy, one of the main difficulties they face is evaluating the alternative measures that answer to their needs and vision, and are the most effective and easy to implement.

The classic transportation models and methodologies for evaluating the different scenarios of alternative measures and infrastructure are very demanding because they use a large amount of data, simulation procedures, and complex assignment algorithms to calculate the effect on transport and the environment. Nevertheless, social, financial, or institutional parameters are not taken into account. For this reason, these models can be used mostly for calculating the effect of the already-selected group of measures to evaluate their specific impact on the traffic and their performance with the existing transportation network.

The development of a methodology that can quickly adapt to each stakeholder group's needs, with a capacity to highlight the preferable list of measures included in the sustainable mobility plan of an urban area could address the specific conditions. The methodology should consider different scientific experts (urban planners, transportation engineers, environmental engineers, economists, sociologists, groups of citizens, etc.) and the legal and institutional barriers for each measure implementation.

The prerequisites mentioned above led to the use of multicriteria analysis for implementing the methodological framework, which is presented in the current work. The current framework is based on calculating the Sustainable Mobility Efficiency Index (SMEI) for each proposed measure of a Sustainable Urban Mobility Plan, using specific weights that a group of experts gives to the central policy, difficulty objectives, and the result indicators. After evaluating the intensity with which each measure affects the result indicators/objectives of SUMPs and assessing their difficulty to be implemented, the final calculation of the index took place. The definitive ranking of all the measures resulted from this procedure can be a criterion for allocating the actions per time horizon.

The specific framework was developed upon the needs of the Greek authorities (staff of municipalities and regions) who are trying to follow the SUMP cycle's step-by-step procedure, facing many difficulties and barriers to cooperation in the opinions exchange procedure. The framework's challenge is the complexity of using the multicriteria analysis methodology, collecting all the different and sometimes contradictory planning thoughts of the involved parties, creating a final list of measures which reflects their views and preferences, and contributing to the development of a commonly accepted plan.

The application of the specific framework to an extensive list of relevant authorities could create a dedicated list of weights and a particular ranking of measures. Analysis of differentiation between different planning area characteristics or profiles of experts will be further explored.

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