Using AHP methodology for prioritizing the actions in the transport sector in the frame of SECAPs

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***Abstract*—The drafting of the Sustainable Energy and Climate Action Plan, required for the local authorities joining the Covenant of Mayors initiative, is an opportunity to plan actions reducing greenhouse gas emissions in the transport sector. Choosing the measures to implement requires the application of a methodology that compares them, considering costs and impacts in terms of energy consumption, emissions reduction, and social benefits. The paper aims to develop a method based on the typical approach of the Analytical Hierarchy Process, supporting decisions in the transport sector in the frame of the drafting of SECAP. The method allows determining the priority actions and the optimal allocation of economic resources, through the definition of indicators and weights, obtained by involving stakeholders in the process.**

Keywords—Sustainable Energy and Climate Action Plan (SECAP), transport sector, Decision Support System (DSS), Analytic Hierarchy Process (AHP), Multi-Criteria Decision Analysis (MCDA)

I. INTRODUCTION

In recent years, the European Union has been promoted many initiatives to reduce CO2 emissions and energy consumption by the member states. The EU has set ambitious but necessary targets, aiming to reduce its total emissions by at least 20% compared to 1990 by 2020 [1] and 40% by 2030 [2]. Therefore, many political initiatives, legislative initiatives, regulatory and economic measures implemented for the various activity sectors have had as their objective the limitation of the levels of atmospheric pollution and the fight against climate change [3]: encouraging the use of renewable sources for energy production, promoting electric mobility, limiting emissions for vehicles, regulating energy efficiency in the residential sector, the abolition of certain substances in production, the promotion of new technologies and the adoption of the Sustainable Urban Mobility Plans (SUMP).

An interesting initiative is the Covenant of Mayors (https: //www.covenantofmayors.eu), promoted by the European Commission since 2008. The initiative gathers 10,065 local authorities and almost 320 million citizens affected by the implemented measures and policies in March 2020. The peculiarity of the initiative lies in the direct involvement of local authorities, which commit to reduce greenhouse gas emissions by 40% by 2030 through the adoption of a Sustainable Energy and Climate Action Plan (SECAP) within two years. In this planning tool, the technical measures that policymakers commit to implement in the various activity sectors for the emissions reduction must be programmed and described. SECAP must be approved by the municipal council and accepted by the Covenant of Mayors Office. The signatories also commit to prepare a Baseline Emission Inventory to better understand the starting situation of the territory. They also commit to send a monitoring report every two years. The Covenant of Mayors was a useful tool already in the early years of its conception, helping to ensure that the emissions reduction targets set for 2020 were achieved in many member countries.

The paper aims to propose a method to support local authorities in choosing the actions to be implemented during the drafting of SECAP. The policymakers deal with limited economic resources; therefore, the development of a methodology that allows policymakers to establish which priority actions must be fund to achieve the goal of reducing emissions and increasing energy efficiency is really important. In particular, the transport sector was analyzed in this paper, identifying all the infrastructural measures or policies that can be adopted by local authorities to reduce emissions and energy consumption in the transport sector.

Transport is a major contributor to greenhouse gas (GHG) emissions in the EU-28 [4]. As shown in Figure 1, transport (including air transport emissions) was responsible for 24.6 % of total emissions in 2017. Within the transport sector (including air transport and maritime emissions), road transport accounts for 71.7 % of emissions. Within road transport, cars account for 60.6 % of emissions, vans for 11.9 % and trucks and buses for 26.3 %. Since urban traffic is one of the major causes of air pollution in cities, more measures need to be taken to reduce its impacts, which can lead to health problems and can also damage monuments in city centers.

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Some of these measures are foreseen in other planning tools, such as SUMP or other urban mobility plans. Therefore, interoperability and consistency between the plans that the local authorities adopt must be taken into consideration in the drafting of SECAP. With SECAP, the policymakers can quantify in terms of impact in reducing emissions some of the policies present in the SUMP and the other mobility plans. They can also broaden the range of measures already financed, proposing new ones.

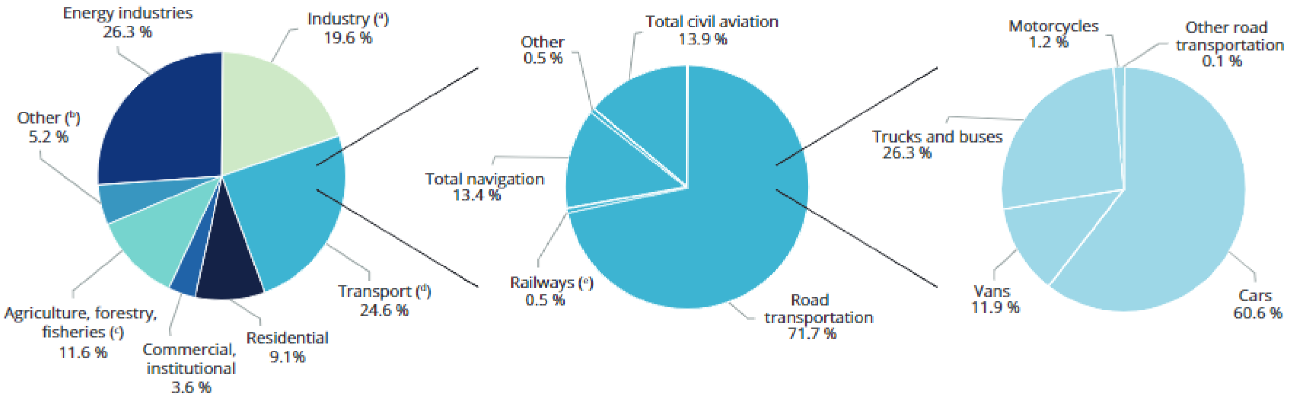

Fig 1. Transport emissions as a share of total EU-28 GHG emissions and road transport emissions as a share of EU transport GHG emissions (2017). Source: EEA (2019a).

The proposed methodology, based on the analytical hierarchy process [5] [6], allows comparing the actions that can be implemented, considering energy consumption, environmental and social benefits, and costs, aiming the optimal allocation of the available economic resources and the assessment of the most convenient measures.

After an analysis of the scientific literature on SECAP and on the application of the AHP method in Section II, Section III gives a brief overview of the actions that can be implemented in the transport sector to reduce emissions and energy consumption; the new methodology will be illustrated in Section IV while the conclusions and the opportunities for future research will be reported in Section V.

II. Background

In the last few years, many researchers have dealt with the role of the SECAP. In [7], considering a sample of 124 European cities which delivered a SECAP, the authors show that local authorities attribute higher potential to actions in subsectors under their direct control (municipal buildings, public transport, municipal fleet, and public lighting) compared to actions in subsectors managed by private actors (households and firms). Furthermore, they found that the category of action delivering the highest share of CO2 emission reductions in the transport sector was represented by the modal shift, which implies a transition from private transport to public and cleaner transport modes. Similar results are obtained in [8]. A quantitative evaluation of the impact on air quality of the measures adopted by several cities after joining the Covenant of Mayors is reported in [9]. The climate mitigation trajectory to 2050 of Covenant of Mayors signatories has been studied in [10], finding that the initiative has a large potential to contribute to ambitious mid-century climate change mitigation targets. In [11], the authors underline that the success of the initiative resides in the engagement of small and medium cities (less than 10,000 inhabitants) in reducing greenhouse gas emissions and how important is the collaboration between different levels of government in the drafting of a SECAP. In [12], to find the best actions to put in place to reduce emissions and energy consumption, the authors propose a novel classification of the actions, helping local governments improving their plan through a validated set of mitigation and adaptation measures. This classification could aid policymakers in identifying innovative solutions for making urban systems more resilient to climate change. Monitoring is also a crucial issue for the success of the actions planned by SECAP, according to [13]. Monitoring has to look at both the progress of every single action and its global environmental effects [14].

In the literature, there are many examples of the application of the AHP method in the transport sector. A review of the literature on this topic is reported in [15]. In [16], the authors present a hybrid approach based on the AHP for evaluating the impact of environment-friendly transport measures on city sustainability. A combination of the AHP method with role-playing games is developed in [17] for the engagement of the stakeholders in complex transport decisions.

III. Measures in the Transport Sector

Many measures can be implemented in the transport sector to reduce greenhouse gas emissions and the energy consumed. Table 1 provides a list of the measures that can be implemented by policymakers within a SECAP. For the preparation of this list, a review of the SECAP approved by several local authorities was made and the most commonly mentioned actions were considered. Furthermore, we also considered the actions generally present in SUMP and other urban mobility plans. Therefore, we included all those measures - also infrastructural measures - implemented in SUMP and already financed, as well as the short-term measures, certainly less expensive, present in the other mobility plans to underline the needed consistency between the different planning tools.

The actions to be considered are those technically feasible by the local authorities in a few years from the approval of the Action Plan. Local authorities can implement measures consisting of public transport improvement, to increase the number of users who choose it as the preferred mode for commuting as an alternative to private cars. Policymakers can implement measures aimed at discouraging the excessive use of private cars, which is the main cause of congestion and pollution in urban areas. Among these, the creation of restricted traffic areas and road pricing are the ones that most allow reducing the presence of cars and the emission levels in certain areas of the city. The promotion of more sustainable modes of transport, such as walking or cycling, as well as the promotion of shared mobility services, complementary to public transport and useful to allow citizens to free themselves from the use of private cars, can be winning actions to lead to a reduction in emissions. Other actions consist of policies promoting the gradual renewal of the circulating vehicle fleet (private and public). Finally, since freight transport is also relevant in the production of emissions in the urban area, effective actions can be the rationalization and the improvement in logistics of urban freight transport.

Local authorities, therefore, have a range of possible alternatives at their disposal and choosing the best combination of actions considering environmental benefits and costs is not always easy. For this reason, it is necessary to develop a decision support methodology that considers both aspects.

IV. The Methodology

To determine the priority actions within the transport sector to be included in SECAP and to be financed and implemented primarily, the analytic hierarchy process (AHP) method has been used. It is a multi-criteria decision analysis (MCDA) method that aims to prioritize a certain set of possible alternatives using a set of criteria.

Consequently, it well supports the planning and decision processes where many alternative policies and infrastructural measures have to be considered and compared based on different criteria. Therefore, this method has been chosen because it is intrinsically capable to take into consideration different ambits, producing a comprehensive assessment. Furthermore, despite based on a rigid structure, it is able to easily embed new evaluation ambits and criteria. The AHP method involves several levels and the construction of a hierarchy. The highest level represents the main goal to be achieved; the intermediate levels are the evaluation ambits and the indicators; the lowest level is the list of the alternative measures to be compared through several indicators.

Giaccone et al. [18] assessed priority actions in the residential sector within the frame of the Energy Master Plan by means of the application of a hybrid AHP method, from which this paper was inspired.

The hierarchical structure provided by the AHP method for achieving the goal (the optimal allocation of economic resources for identifying the actions in the transport sector to be implemented in a SECAP) is represented in Fig. 2. The evaluation ambits proposed here are Energy, Environment, Economy, and Quality of Life.

The energy and environmental aspects are linked to the main goals of SECAP and therefore the inclusion of these ambits is easy to understand. The economic impact of the measures must also be assessed, as local authorities have to deal with a limited budget.

TABLE I. LIST OF THE POSSIBLE MEASURES

Type		**Actions**		
		Description	***Short/Medium Term***	***Code***
Improving the quality and the structure of public transport services		Increase in the number of rides and frequencies	M	1
		Introduction of preferential lanes	S	2
		Tariff integration and tariff management	S	3
		Infomobility	S	4
		Park-and-Ride	S	5
Discouraging the use of private cars		Road pricing	S	6
		Parking pricing	S	7
		Implementation of restricted traffic areas	S	8
		Implementation of 30 km/h zones	S	9
		Improvement of the hierarchy of the road network - elimination of parking lots from the main roads	M	10
Modal shift toward sustainable modes of transport	Promotion of walking	Implementation of pedestrian areas	S	11
		Promotion of pedibus – implementation of safe home-to-school routes	S	12
	Promotion of cycling	Creation of new cycle paths	M	13
		Creation of new cycle docks and facilities	S	14
	Promotion of shared mobility services	Promotion of bikesharing	S	15
		Promotion of carsharing	S	16
		Promotion of taxisharing	S	17
		Promotion of demand-responsive transport (DRT) services	S	18
	Mobility management	Promotion of carpooling	S	19
		Promotion of tele-work and smart working	S	20
Renewal of the vehicle fleet		Renewal of the public transport fleet	M	21
		Renewal of the municipal car fleet	M	22
		Renewal of the private vehicle fleet through car scrappage incentives	M	23
		Promotion of the electric mobility through incentives and realization of public and private electric recharging systems	M	24

Type	Actions		
	Description	***Short/Medium Term***	***Code***
Rationalization of freight transport	Cycle logistics in freight transport	S	25
	Control and management of loading/unloading areas according to differentiated time slots	S	26
	Self-service station for the collection of goods purchased remotely	S	27
	Introduction of restricted traffic areas for freight transport	S	28
Existing transport policies and measures	Policies and measures present in SUMP or other mobility plans that have been already financed	S/M	29

Quality of life was considered as an evaluation ambit since each intervention also has a different effect on the quality of life of citizens and this impact must not be neglected because it affects the success of certain policies and infrastructural measures.

The methodology is based on five steps to follow: the identification of the actions to be considered, the identification of the indicators, the assignment of the weights, the pairwise comparison of the actions, the assessment of the priority actions.

The proposed methodology combines cost indicators with impact indicators (on energy consumption, emissions, and quality of life), allowing a global assessment and a balanced comparison of the measures to be taken. The indicators and the weights assigned to them can be defined with the involvement of the stakeholders. It is, in fact, advisable to involve the various stakeholders of the transport sector in the drafting of the SECAP. They are technicians of the municipal administration, representatives of the Region, representatives of the universities and experts, representatives of the main companies operating in the sector of transport, representatives of major environmental institutions, trade unions and societies promoting sustainable mobility.

Therefore, stakeholders choose the indicators that must be primarily considered in the comparison between the actions. Some of the indicators that are considered fundamental for an adequate comparison between the possible actions and for finding the priority measures are proposed in Table II. However, the stakeholders' engagement process can lead to the choice of different indicators or the proposal of new indicators, to consider the specificities of the municipality.

EN1, the reduced gross energy consumption in the transport sector, was chosen for assessing the effectiveness of the energy-saving measures. The energy intensity, EN2, is the energy required for distance traveled. The Indicator EN3 represents the total amount of energy saved throughout the life span of the proposed actions.

ENV1 represents the CO2 emissions avoided through the life span of the proposed action and is the main indicator of environmental performance. ENV2 is the emission intensity, i.e. the tones of CO2 released per distance traveled.

The main economic indicators are the investment cost for implementing the measure (EC1), the average cost of one saved toe (EC2) and one avoided tCO2 (EC3) at 2030. The economic performance of each action is assessed by other indicators: Net Present Value (EC4), The Internal Rate of Return (EC5) and the Payback Period (EC5). Finally, the increase of working hours, resulting from the adoption of the measures selected in the plan, has been also considered an important indicator.

The indicators QL1, QL2, QL3, and QL4 are linked to the reduction of traffic congestion in the urban road network while the increase in accessibility (QL5) and the accident reduction (QL6) are considered for taking into account the possible social benefits deriving by the implementation of measures in the transport sector. In particular, QL5 has been chosen because the infrastructural measures are more effective if promote an improvement of accessibility towards the travel attractor poles. Accessibility can be determined in many ways. Examples can be found in [19] and [20].

The emissions and the energy consumption for each action could be assessed through several methods found in the literature. For example, the COPERT methodology, elaborated within the European project called CORINAIR, allows estimating road transport emissions and energy consumption linked to each action, considering the modal shift and the new composition of the circulating fleet. An example of the application of the COPERT methodology can be found in [21].

The methodology involves the adoption of local weights "L_2" for the evaluation ambits (second level) and "L_3" for the indicators (third level). These weights are established by stakeholders in a debate through the counting of the preferences. The sum of the weights for the evaluation ambits must be equal to 1: Also the sum of the weights for the indicators within each ambit must be equal to 1. A classical pairwise comparison procedure is carried out at the actions' level (fourth level).

Generally, when two actions of Table I are compared by means of an indicator of Table II (EN, ENV, EC or QL), a coefficient a_{ij}, which describes the relative importance of each action i over another j, is assessed. For example, by comparing action 1 with action 2, a coefficient

$$a_{12} = EN1_1 / EN1_2 \quad (1)$$

will be obtained for the indicator EN1, where $EN1_1$ and $EN1_2$ are the values that the indicator EN1, i.e. the reduced energy consumption, assumes respectively for the Action 1 and Action 2.

This coefficient is calculated for each pair of actions and each indicator and a matrix is created. In total, there will be as many matrices as there are considered indicators.

Once the pairwise comparison matrices are obtained for each indicator, the eigenvectors of each of these matrices have to be calculated for determining the local priority order of all the elements in the matrix.

Therefore, the eigenvector components, v_i, are assessed by the following formula:

$$v_i = \sqrt[n]{a_{i1} \times a_{i2} \times \ldots \times a_{in}} \quad (2)$$

where i = 1,…,n and n is the number of the actions.

These elements need to be further normalized, by applying normalization factors so that their sum is equal to 1.

The normalization factors x_i are computed as follows:

$$x_i = v_i / S \tag{3}$$

where

$$S = \sum_{i=1}^{n} v_i \tag{4}$$

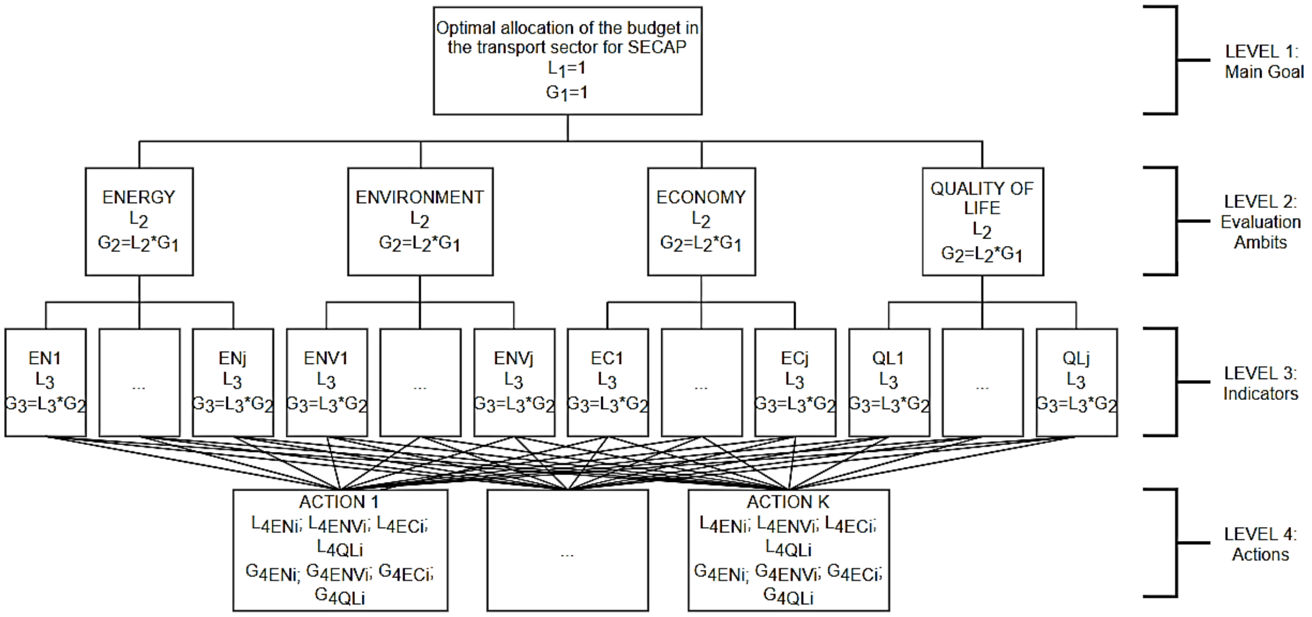

Fig 2. Hierarchical structure of the AHP method.

TABLE II. INDICATORS SELECTED, GROUPED BY EVALUATION AMBIT

Energy	**Environment**	**Economy**	**Quality of Life**
EN1 Reduced energy consumption in the transport sector (ktoe/year) EN2 Energy intensity of the transport sector (Mj/passenger km) EN3 Saved energy in the transport sector during the life span of the proposed action (toe)	ENV1 CO_2 emissions avoided through the life span of the proposed action (tCO_2) ENV2 Emission intensity (tCO_2/passenger km)	EC1 Action cost [€] EC2 Average cost of one saved toe at 2030 for the public administration (€/toe) EC3 Average cost of one avoided tCO_2 at 2030 for the public administration (€/tCO_2) EC4 NPV (Net Present Value) [€] EC5 IRR (Rate of Return of the Investment) [%] EC6 PBP (Payback Period) [years] EC7 Increase in working hours	QL1 Average car speed [vehicle km/vehicle hours] QL2 Average public transport speed [passenger km/passenger hours] QL3 Travel time reduction for private vehicles QL4 Travel time reduction for public transport QL5 Increase in accessibility QL6 Accident reduction

The elements x_i are the components of the local priority vector L_4 for a certain indicator, that sets priorities for the actions in relation to the indicator considered. A local priority vector must be calculated for all the indicators.

At this point, for determining the global priority vector for each indicator, the principle of hierarchical composition is used. Therefore, the elements x_i, of the local priority vector are multiplied by the corresponding global weight of the element of the upper level. For the hierarchical structure represented in Fig. 2, the global weight for the fourth level and for the indicator A is calculated by the following formula:

$$G_{4A} = G_1 \times L_2 \times L_3 \times L_{4A} \tag{5}$$

Finally, for each action, the local weights associated with this action are converted into global weights. All these global weights are summed up obtaining the importance of the action in achieving the main goal.

V. CONLCUSION

During the implementation of the Sustainable Energy and Climate Action Plan, the signatories must find the actions to put in place to achieve the objective of reducing energy consumption and greenhouse gas emissions. The range of possible actions is large and economic resources are limited. To establish which interventions are most effective to achieve the goals and where to allocate resources, assessing the priority actions, it is necessary to develop a simple methodology that allows comparing the possible measures considering energy, environmental, economic and social impacts. The paper illustrates a methodology, based on multi-criteria decision analysis and analytic hierarchy process, which, considering specific indicators for each evaluation ambit, leads to the determination of the measures to be included in the Action Plan and to be primarily implemented. The methodology took into consideration the fundamental role of the stakeholders, who can propose new indicators and assign weights according to the specific situations of the Municipality. The involvement of the stakeholders is considered one of the pillars of the correct drafting of the Action Plans, according to the guidelines drawn up by the Joint Research Center (Institute for Environment and Sustainability, IES) of the European Commission [22]. The role of the stakeholders in the proposed methodology determines flexibility in the application of the method and the implementation of the planning tool. This flexibility is essential to make the method generalizable and applicable to any municipality that wants to join the Covenant of Mayors. Depending on the CO2 sources present in the municipal area and the available economic resources, some sectors, some measures, and some indicators will be more appropriate than others, and the stakeholders will contribute to assessing the weights to be attributed.

The proposed methodology also highlights the importance of not neglecting the presence of other existing mobility plans and seeking harmonization between them. SECAPs must be consistent with the other plans that the local authorities have adopted in the transport sector, such as SUMPs. In particular, it is necessary to consider all those measures and policies that have been already financed (also short-term and medium-term infrastructural measures).

Future research will focus on applying the methodology to other sectors. In fact, the methodology could also be extended to other sectors that are involved in the production of CO2 emissions and energy consumption, such as the waste or the building sector. This can be achieved simply by taking into consideration the technically feasible measures for the other sectors and adding new indicators, thanks to the engagement of experts and stakeholders. The evaluation ambits chosen may also apply to other sectors. For example, the indicators used in [18] for the building sector could be added for extending the AHP method also to this sector. In this sense, the methodology can be a broad decision support tool for policymakers and the basis of a platform for the development of SECAPs. The result will be the identification of priority actions not only in the transport sector but in all the different sectors considered, as well as the optimal allocation of resources between actions of different nature.

To further our research we are planning to analyze a case study to verify the effectiveness of the method.

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