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Economic and environmental analysis of measures from a Sustainability Urban Mobility Plan – Application to a small sized city

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Abstract

Urban mobility causes significant negative externalities namely emissions from individual transport. Sustainable Urban Mobility Plans (SUMPs) have been designed and implemented in an attempt to reduce transport-related externalities, setting several measures to improve the efficiency and sustainability of urban mobility. The assessment of environmental and economic impacts of the measures predicted in a SUMP can be potentially useful for supporting decision-making and encouraging policy makers to implement the proposed measures with success.

In this paper, a case study is performed to analyze the economic and environmental impacts of the measures predicted in a SUMP of a small sized city in Portugal. It consists of estimating the emissions and external costs for a base live scenario and after the measures are implemented, as well as to perform an economic analysis based in economic indicators such as Net Present Value (NPV) and Internal Rate of Return (IRR). All the measures equated showed a great potential of emissions reduction. One of the measures can reach a CO_2 reduction of about 9% and a reduction of external costs of around 11%. The measures were all aggregated as a single project, analyzing the economic aspects, using the external costs as a mean of economic measurement, it was possible to conclude that the project is profitable after 6 years and half with a NPV of 1.245.448€ and an IRR of 10% (which is above the discount rate of 2,3%).

Keywords: Sustainability Urban Mobility Plan; External costs; Environmental impacts; Economic analysis.

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1. Introduction

In the European Union (EU) around 75% of the population lives in urban areas (cities, towns and suburbs) (EC, 2017). Urban mobility is responsible for 40% of CO_2 emissions and 70% of the other pollutants (IT, 2018). Urban mobility is a major concern among EU citizens, and 9 out of 10 EU citizens believe that improvements should be made regarding urban traffic. To tackle these concerns the urban mobility Action Plan suggest the creation of Sustainable Urban Mobility Plans (SUMPs) where practical actions to improve the quality and sustainability of urban mobility are designed (EC, 2009). The aim of a SUMP is to create an urban mobility plan that addresses various objectives such as the reduction of the pollutant emissions, improvement of the efficiency and cost-effectiveness of the transport system, improvement of safety and security, among others. The improvement of Public Transport (PT) or the incentive to use active modes of transport (e.g., bicycle) are among the general measures that should be implemented (EC, 2014).

May (2015), suggests eight areas where research should be focused on, improving the processes of benchmarking and target setting is one of them, this paper fits in this area of research as it tries to benchmark and set targets to some measures proposed in the SUMP of a small-sized city. The literature review will focus in other studies made to evaluate the performance of SUMPs, methodologies, indicators and other case studies.

Methodologies and analyses to evaluate the effectiveness of applied measures in a SUMP should be conducted, being the CO_2 savings one of the indicators that translates the effectiveness of a SUMP. It is then possible to estimate the cost effectiveness of a measure by calculating the amount of money per each quantity of CO_2 saved and the investment for a particular measure (Diez et al., 2018):

A set of performance indicators to evaluate the sustainability of urban mobility are used to compare various sustainable mobility indicators with previous situation (base scenario). The indicators are used to compare the performance of the 10 largest Italian cities, being the indicators, for example, concentration of air pollutants, number of road fatalities, performance of public transport, modal share and others (Danielis et al., 2018).

Measures from SUMPs are modelled to 642 cities in Europe and the impacts that these measures have in the air quality are studied such as the urban background concentrations of $PM_{2,5}$ and NO_2, the results show that the SUMPs can improve both indicators (Pisoni et al., 2019).

The main objective of this work is to assess the environmental and economic impacts that a set of measures in a SUMP might have when applied and to analyze the associated cost-benefit, being as a novelty the treatment of the measures as a single project and also the quantification of the emission of other pollutants besides CO_2. The assessment of positive impacts can encourage the political authorities to promote active modes of transport and raise awareness among the population., and this paper fits in the attempt to improve and develop indicators to benchmark and set targets to the performance of SUMPs.

2. Methodology

In order to assess the performance of a measure, the environmental and economic impacts of such measure will be compared with the Baseline Scenario (BS) and a cost-benefit analysis will be performed based on three possible scenarios: 1) conservative (S1); 2) neutral (S2) and 3) optimistic (S3). Nonetheless all scenarios equated will be an improvement when regarding the BS. The measures with most potential out of the Sustainable Urban Mobility Plan will be selected. The case study will be in Águeda, Portugal, a city with approximately 15.000 inhabitants within a municipality of 50.000 inhabitants. A mobility plan was created in order to promote sustainable mobility to be applied until 2020 (Municipality of Águeda, 2013). The methodology followed to perform the necessary estimations can be seen in the Fig. 1. Further explanations of the steps are in: 2.1. Environmental impacts, 2.2. Economic impacts.

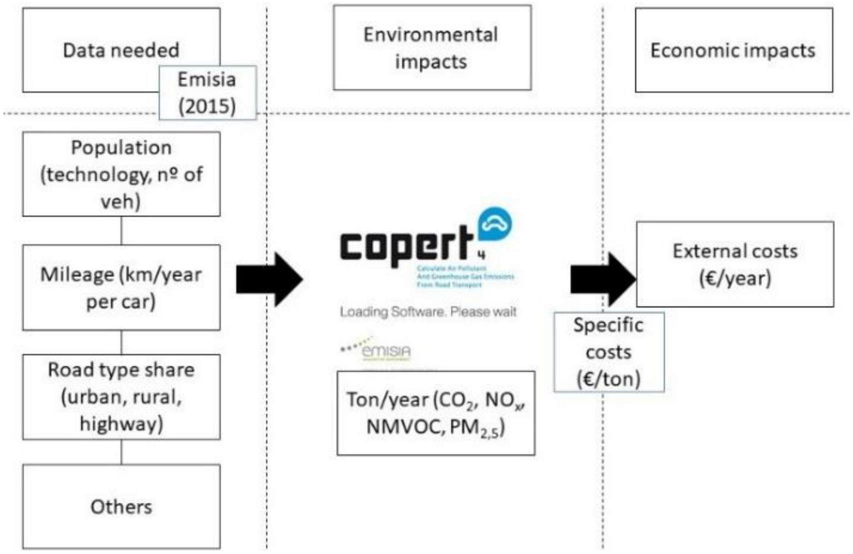

Fig. 1 - General view of the methodology applied.

2.1. Environmental impacts

To evaluate the environmental impacts, the emissions of carbon dioxide (CO_2), Nitrogen Oxides (NO_x), Non-methane Volatile Organic Compounds (NMVOC) and Particulate Matter ($PM_{2,5}$) will be analyzed. The emissions were estimated using the software COPERT (Emisia, 2017), which is an average speed-based emissions model widely used in Europe. To proceed with the calculation, one needs data related to the local fleet distribution, in particular, the population (technology and nº of vehicles per tech.), mileage (km/year per car), road type share (urban, rural, highway), physical characteristics of each tech and others. The input data about the BS for this municipality can be obtained by order in Emisia, (2015). With such data, annual emissions can be estimated using this software.

To assess the environmental impacts, some scenarios were established and will be further evaluated. Moreover, a comparison between the BS and the proposed scenarios (S_i) will be performed to calculate the Environmental Savings (ES_x), by subtracting the total emissions estimated for S_i to the total emissions of BS (x represents the pollutant and i represent the proposed scenario with i = {1,2,3}).

2.2. Economic impacts

The impacts associated to the road traffic pollutant emissions can be monetized following the Impact Pathway Methodology that internalizes the monetary costs that traffic-related emissions cause to society, which reference values are provided in (Korzhenevych et al., 2014). Each pollutant has a specific cost to society (Table 1), and which was estimated based on the country characteristics by using a top-down methodology where average national data is applied (Korzhenevych et al., 2014).

Table 1 - Environmental external costs for Portugal (Korzhenevych et al., 2014)

Pollutant	Specific cost (€/ton)		
CO_2	90		
NO_x	1957		
NMVOC	1048		
$PM_{2,5}$	Rural	Suburban	Urban
	18371	49095	196335

For the sake of simplicity, in the present study the specific cost of $PM_{2,5}$ will be always considered as Urban.

Having the estimation of ES (ton), the economic savings can be computed by:

$$ECS_x = ES_x \times SC_x \tag{1}$$

where ECS represents Economic savings (€) and SC denotes the Specific costs (€/ton).

A cost-benefit analysis was also performed and it consisted in the estimation of Net Present Value (NPV) (2) (Kurt, 2003), Internal Rate of Return (IRR) and a ratio between the investment and CO_2 saved as a performance indicator for each measure and scenario that translates the amount of investment needed to save 1 ton of CO_2 (3).

$$NPV = \sum_{t=1}^{T} \frac{C_t}{(1+r)^t} - C_0 \tag{2}$$

where C_t = net cash flow inflow during period t; C_0 = total initial investment costs; r = discount rate and t = number of periods.

$$\frac{€}{\text{toe}} = \frac{Investment\ (€)}{\text{toe}_{CO2_{saved}}} \tag{3}$$

The usage of NPV and IRR is used as a possible indicator of economic performance from the measures under study, to analyze the trade-off between investment and environmental gains in form of external costs.

2.3. Selection of measures and scenarios

The SUMP of Águeda (Municipality of Águeda, 2013) was analyzed, and the following measures (Table 2) and their impacts (Table 3) were defined based on an assumption of 3 different scenarios, a conservative, a neutral and an optimistic after the performance of sensitive analysis. The actions for each measure were also taken from Municipality of Águeda (2013).

Table 2 - Measures and actions (Municipality of Águeda, 2013).

id	Measure	Action
M1	Promote active mobility (bicycle).	Investment in the cyclist network. Bike-share system. Awareness actions.
M2	Buy new vehicles.	Awareness actions and monetary incentives.
M3	Improvement of truck traffic logistics.	Make the trucks go through less congestion routes, traffic restrictions at the urban roads by optimize the commercial logistics.

Table 3 - Impacts of the selected measures.

id	Impacts (scenarios)		
	Conservative (S1)	Neutral (S2)	Optimistic (S3)
M1	1000 trips/day under 4km are made by bicycle	2000 trips/day under 4km are made by bicycle	3000 trips/day under 4km are made by bicycle
M2	5% of people with < EURO3 vehicles buy EURO6 vehicles.	10% of people with <EURO3 vehicles buy EURO6 vehicles	15% of people with <EURO3 vehicles buy EURO6 vehicles
M3	Urban environment km travelled decrease to 10%	Urban environment km travelled decrease to 7.5%	Urban environment km travelled decrease to 5%

The selected measures have different impacts. Concretely, M1 can make the amount of trips made by individual car decrease, 92% of average distance travelled by bicycle is under 4 km. In the base scenario, 25.221 trips made by car are under 4km, so it is realistic that some of this trips may be performed by bicycle. Municipality of Águeda b, (2013) suggests that 3.000 of this trips under 4km can be made by bicycle (for an optimum scenario) and for a more pragmatic scenario, around 1.600 trips may be done by bicycle (mainly home – leisure and shopping activities, average distance of ~2,7km).

M2 consists in replacing older and more polluting vehicles for new ones more environmentally friendly, which can have a significant impact in the reduction of pollutant emissions. Monetary incentives based on the environmental saving achieved by car bought were taken in account in the economic analysis.

Finally, the M3 is intended to remove trucks from the urban environment by optimizing the logistics in the municipality, at this stage about 17% of the kilometers travelled by trucks are made in urban areas (Emisia, 2015).

3. Results

3.1. Base scenario

In Águeda Municipality, there are approximately 32.000 vehicles, being 77% of them passenger cars (49% diesel, 49% gasoline, 1% LPG and 1% hybrid), the passenger cars perform 85% of all the km travelled within the municipality (Emisia, 2015).

Most of passenger vehicles are old in terms of technology, in particular, 8% are pre-EURO, 56% between EURO1 and EURO3, and 36% EURO4 or above, while in terms of kilometers travelled, pre-EURO cars perform 4% of the kilometers travelled, EURO1-EURO3 52% and >EURO4 perform 44% (Emisia, 2015).

The emissions and the economic impacts of all vehicles and their relative costs can be seen in the Table 4.

Table 4 - Annual emissions and their costs for all modes of transportation in the municipality of Águeda.

Pollutant	Emissions (ton)	Costs (€)	Relative costs (%)
CO_2	66.549,27	5.989.435	63%
NO_x	245,25	479.964	5%
NMVOC	94,94	99.495	1%
$PM_{2,5}$	15,35	3.013.615	31%

The total environmental costs are almost 9.600.000€.

3.2. Alternative scenarios

M1 consists in the promotion of active modes of transport in the form of cycling, for three different scenarios by conducting awareness actions, construction of cyclist paths and investment in bike-sharing schemes. The emissions and costs savings for the three scenarios are presented in Table 5.

Table 5 – Estimated emissions and monetary savings for M1 for three different scenarios.

Scenarios	CO_2 (ton)	NO_x (ton)	NMVOC (ton)	$PM_{2,5}$ (ton)	Total savings (€)
S1	357,19	1,12	0,40	0,07	49 281,63
S2	715,77	2,24	0,81	0,15	98 753,18
S3	1 073,41	3,36	1,21	0,22	148 097,28

For the three scenarios (S1, S2, S3), it is possible to reduce the CO_2 emissions by 0,54%, 1,08% and 1,62%, respectively. In terms of external costs, they can be reduced by 0,51% for the first scenario, 1,03% for the second scenario and 1,55% for the third scenario.

Incentives to increase new vehicles (>EURO6) to substitute the older and more polluting ones can be a very efficient measure to reduce emissions and external costs. In the action plan of the Águeda Municipality, only awareness actions are scheduled. The emissions and costs savings for the three scenarios are displayed in Table 6.

Table 6 – Estimated emissions and monetary savings for M2 for three different scenarios.

Scenarios	CO_2 (ton)	NO_x (ton)	NMVOC (ton)	$PM_{2,5}$ (ton)	Total savings (€)
S1	2 345,06	9,01	4,56	0,71	373 684,16
S2	3 871,40	16,56	8,08	1,34	653 310,00
S3	5 509,77	26,00	11,48	2,29	1 009 087,04

With this measure fully implemented, results show that CO_2 emissions can be reduced by 3,52% (for the conservative scenario) and the external costs 3,90%. For the most optimistic scenario, the CO_2 reductions can be approximately 9%, while the external costs can be reduced in almost 11%.

The improvement of the trucks traffic logistics by removing them from urban centers can lead to a reduction of the CO_2 emissions, as well as the external costs. The results for the three scenarios equated are presented in the Table 7.

Table 7 – Estimated emissions and monetary savings for M3 for three different scenarios.

Scenarios	CO_2 (ton)	NO_x (ton)	NMVOC (ton)	$PM_{2,5}$ (ton)	Total savings (€)
S1	149,70	1,60	0,13	0,06	28 665,83
S2	219,66	2,35	0,20	0,09	42 062,34
S3	289,62	3,09	0,26	0,12	55 458,85

It can be observed that the reduction of CO_2 does not significantly vary between the three scenarios, nevertheless, the reductions lie between 0,22% and 0,44%. With respect to the external costs, the saving values range between 0,30%, for the conservative scenario, and 0,60%, for the optimistic scenario.

3.3. Economic analysis

In order to perform the cost-benefit analysis, the investments needed to implement the actions that are described in Table 2 were considered taking into account the values referred in the Action Plan (Municipality of Águeda, 2013). The measures investments and the respective savings were all aggregated as a single project. The external costs is used as an indicator that illustrates the economic value of a measure for this case study. The timespan considered is 10 years, which is more or less the lifetime of a new vehicle in Portugal and as a performance indicator the NPV and the IRR will be calculated. In the lack of a better reference value, the discount rate considered will be fixed and close to the one given by the public bank entity in Portugal for a 10 years' mortage loans (r = ~2,3%) (CGD, 2018). The annual cash flow (C_t) considered will be the one obtained for S1, the conservative scenario, which is around 451.000€, altogether the investment will be around 2.700.000€ (C_0). The results can be observed in Fig. 1. An indicator that relates the investment and the CO_2 savings is also estimated for each measure and scenario (Table 8).

The investment for M1 is approximately 1.500.000€ and is mainly designed to the construction of cyclist infrastructures. To achieve a good shift to active mobility modes, it is essential that the infrastructures' conditions are good, however it involves large investment. Nonetheless if the awareness actions and the infrastructures are effective, they can lead to a modal shift greater than the one considered in the optimistic scenario.

For M2, the investment is mainly designed for awareness actions, comprising approximately 17.500€. Considering the high environmental benefits of this measure, an economic or fiscal incentive to shift from old cars to new cars should be equated in order to potentiate the measure. These variables will be taken in account in the analysis. It is suggested an incentive of 1.500€ per car (makes a total of 1.155.000€ for S1), which is more or less three times the average value of economics savings per year.

In the case of M3, the investment is approximately 10.000€ and is mainly devoted to the improvement of the urban logistics in Águeda Municipality.

For the time span of 10 years, the NPV is 1.245.448€ and the IRR is 10%. The NPV is greater than 0€ and the IRR is greater than r (10% > 2,3%), which makes the project economic viable for the timespan considered. Analyzing the Fig.2 is possible to notice that the project starts to be profitable after 6 years and half.

In the table 8 it is possible to see the indicator €/tonCO_2 that translates the amount of investment needed to save 1 ton of CO_2. The results are in a timespan of one year, and the measure with best performance is M3 with 104€/tonCO_2 for S3.

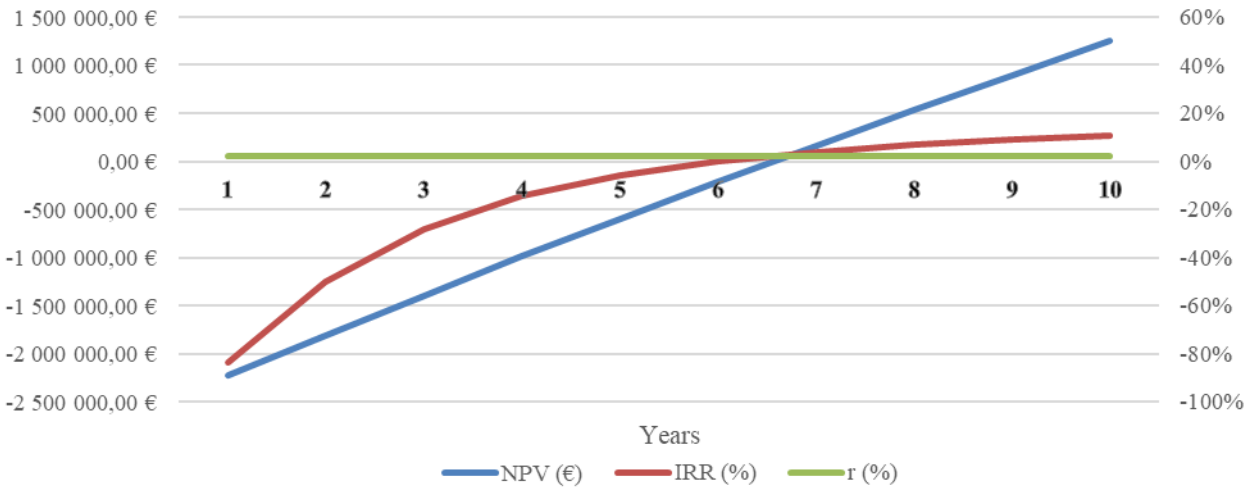

Fig. 2 - Economic analysis of the project.

Table 8 - €/tonCO_2 analysis for three measures and scenarios for a timespan of one year.

	S1 (€/tonCO_2)	S2 (€/tonCO_2)	S3 (€/tonCO_2)
M1	12.901	6.438	4.293
M2	1.498	1.810	1.903
M3	200	136	104

4. Discussion and conclusions

This paper presents a methodology and a case study for an environmental and economic assessment of measures from a SUMP of a small-sized city in Portugal.

Three measures with different objectives and three different scenarios of effectiveness were presented. The first measure considered (M1) consists in promoting cycling, the second measure (M2) involves the modernization of the local fleet, and the third measure (M3) is regarding the trucks logistic optimization.

The results for M1 show that the emissions of CO_2 can decrease from values between 0,5% and 1,6%, while the external costs can decrease 1,6%. To save 1 ton CO_2 (in a timespan of 1 year) 4.293€ (S3) would be needed. In case of M2, this measure has a huge potential of reduction of both emissions and external costs, the CO_2 emissions can be reduced by values around 4% and can extend to a reduction of almost 9%. The external costs may have a reduction of about 11% and the €/tonCO_2 for S3 is around 2.000€. Finally, for M3 the reduction of emissions is around 0,5% being the external costs reduction almost 0,6%. The indicator €/tonCO_2 for this measure is 104€/tonCO_2 for S3. The values of the indicator €/tonCO_2 are for 1 year of CO_2 savings, the performance of each measure may change if the timespan is extended.

In the economic analysis performed, the three measures were aggregated in one single project with a lifetime of 10 years. The results show that the project starts to be profitable after 6 years and half, with a NPV of 1.245.448€ and an IRR of 10% which is above the discount rate (r = 2,3%).

This methodology can be applied at a local or country level, as long as the minimal information needed is accessible. The methodology can also be used to perform comparative analyses between cities, regions or countries. The methodology presented in this paper can be used to benchmark and to have a set of indicators able to evaluate the performance of a set of measures from SUMPs.

Future research is expected to include external costs regarding noise, congestion and road accidents. Furthermore, we also intend to perform comparative analyses between small-, medium- and large-sized cities. Alternative forms of analyzing the economic value of the measures will also be undertaken.

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