Public transport towards sustainability in midsized municipalities

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Abstract: The concept of sustainable urban mobility is related with the movement of people and goods in urban areas. However, this perspective is restrictive when the purpose is to address the problem of sustainability to an urban system of transport, in a big city, or as in this work, in urban areas of small and midsized municipalities, particularly in relation to the evaluation of economic, social, environmental and governance dimensions of the sustainable mobility. The assessment of mobility in urban areas implies the characterization of such areas, particularly in terms of geographic and socio-economic perspectives in order to understand and justify some issues of the existing relation between land use and transports. The framework of the transport system is related with the size of the municipalities. In this work an evaluation model of sustainability is proposed - that can be applied to evaluate and compare the level of sustainability in different urban areas of a system of public transports by bus, which can be also applied to other modes of transport. The model consists of a previous selection of indicators that characterize all dimensions of sustainability, which are then used in a multicriteria analysis. The weight of the indicators is defined by different groups of stakeholders related with the public transport system, mainly those concerned with decision-making process to promote its use at a local level, with the intention of defining priorities for improvement of public transport.

Key-Words: - urban mobility, sustainable mobility, bus, small municipalities

1 Introduction

Regardless of the size of the urban agglomerates and the main areas of activity, the general conditions of access and mobility are usually directed to the use of private transport instead of other more sustainable and equitable modes of transport, such as public transport, walking and cycling. Therefore, it is necessary to counteract this trend by proposing measures for small or midsized municipalities to promote the movement of people in a sustainable way, considering its mobility needs.

This work consists in evaluating the level of service in terms of sustainability of public transport of the main urban agglomerates of a municipality in order to establish the level of priority for action on this branch of mobility. Typically in midsized municipalities this service is ensured by buses.

The majority of the 308 Portuguese municipalities are considered to be of small or midsized dimension, particularly in relation to the resident population. According to the Law 22/2012 of 30th May, which defines the reorganization of territorial administration, municipalities are classified in three levels based on population density and the number of inhabitants. Municipalities classified on level 2 and 3 are within the required parameters for this study. Level 2 comprises municipalities with a population over 100 inhabitants per km2 and 25000 to 40000 inhabitants, while level 3 refers to more than 100 inhabitants per km2 and a population of less than 25000 inhabitants.

The midsized municipalities have, in general, a strong rural character, with high levels of territory dispersion and low levels of accessibility. These two aspects are also complemented by a generally low level of development and with an ageing population, with specific mobility needs. Traditionally, most of the short journeys are made by foot and long journeys in a private (cars) and public (bus) transport.

The municipal public transport system is based on a rural bus service that serves a set of urban agglomerates within the municipality, but with completely different standards and requirements of an urban service, which contribute to draw people away from this mode of transport.

In order to understand the level of service that a municipal bus system should offer to its population and the role that this mode of transport should have to achieve higher levels of a sustainable mobility for midsized municipalities, an evaluation methodology in the municipality of Marco de Canaveses located in Northern Portugal will be presented.

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2. Sustainability dimensions of an urban mobility

The World Commission on Environment and Development [1] defined sustainability as the "development that meets present needs without compromising the ability of future generations to meet their own needs". Conventionally, sustainability covers the social, environmental, economic dimensions of a policy, program or project. These dimensions are intrinsically linked. To evaluate sustainability it is necessary to set up a group of indicators that include time and spatial dimensions, as well as a tendency on a phenomenon evolution [2].

Since 1995 the United Nations introduced the fourth dimension of sustainable development, the institutional dimension, according to the scheme of Figure 1 [3].

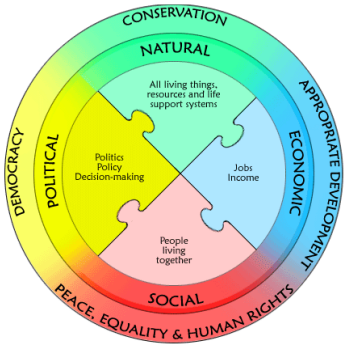

Fig. 1 - The four dimensions of sustainable development (www.unesco.org)

In some applications and stages of sustainability, the institutional perspective, or governance, is dubious and very difficult to apply. On the study of the sustainable mobility at the local level of municipalities, this dimension is fundamental, since it incorporates part of the political and decision-making process, mainly in the assessment and application of sustainable programs, plans and actions.

The applicability of the concept of sustainable urban mobility is a matter of high complexity, given the multiplicity of factors involved. The difficulty to identify and characterize factors that influence urban mobility is linked to the evolution and expansion of urban areas that has been taking place very rapidly [4]. According to Ribeiro et al. [5], the concept of sustainability has a variety of interpretations and applications, thus it is difficult to obtain a practical and objective definition. Despite the difficulty in accurately defining the concept of sustainable urban mobility, its application to specific situations allows a better understanding of the scope of its meaning [6]. Sustainable mobility in an urban environment should reflect a balance between the uses of different modes of transport and always ensure the accessibility of individuals to different forms of travel and services in urban areas.

The use of mass public transport can be very restricted and constrained according to the main characteristics of the covered area (urban, suburban and rural). One of the main issues in the implementation of a sustainable public transportation system in rural and low density areas is the depopulation and territorial dispersion, which makes public services economically and environmentally unviable.

3. Selection of sustainability indicators to assess a public transport system

The principles underlying the selection of indicators for the assessment of a sustainable transport system must be based on the assumption that the measurement process is in line with the established objective [7]. In this context, indicators may include different levels of analysis, reflecting the decision processes (according to the quality of planning), responses (travel patterns), physical impacts (emission levels and accident rates), effects on people and the environment (injured, dead and ecological damage) and economic impacts (costs due to accidents and environmental degradation). Despite the wide scope of the indicators, it is important to ensure that there is a direct independency between them (in terms of variables correlation) under the penalty of the same effect being considered twice.

The process of selection of indicators should reflect an equitable distribution among the four dimensions of sustainability, including the aspects of governance associated to the institutions, in order to make it easier to evaluate a certain process through a simple and reliable data collection [7].

Although there is not a unique set of performance indicators to evaluate a system of public transports, several authors [8-11] presented a diverse list of principles and criteria that a system must provide, for operators and passengers.

Litman [7] established a set of performance indicators according to the categories associated with the different dimensions of sustainability, the potential use of these indicators depending on the type of analyses, relevant issues to the community or specific aspects of the transportation system. In order to relate land use with urban transportation, Campos and Ramos [12] defined a group of performance indicators to evaluate the level of

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sustainability in urban mobility, resulting in several indicators associated with public transport service, particularly on the social and environmental dimensions of sustainability, which were integrated in the methodology proposed in this work.

3.1. Proposed indicators for the assessment model of public transport system

According to the spatial dimension and main public transport characteristics of small and midsized municipalities in Portugal, a set of indicators were selected and proposed to evaluate the level of sustainability associated with this mode of transport, which in this work is a bus service. In Tables 1, 2, 3 and 4 are presented lists of indicators to be used in the assessment model in terms of the social, economic, environmental and governance dimensions. It also includes a description and level of data availability (A – easy; B – reasonable; C – difficult) for each indicator.

Table 1 - Indicators for public transport on buses – economic dimension

Economic dimension			
Domain	Indicator	Description	Data
Bus operation	Course average speed	Average speed measured within each cluster including downtime	B
	Delay per km	Delay within each cluster against the estimated time of passage at each bus stop	B
Operator costs	Energy cost per capita	Amount of fuel consumed by bus within each cluster per capita	C
	Operating costs per inhabitant	Operating costs per capita of each cluster	C
Feasibility	Average occupancy rate	Average occupancy by bus and by cluster	B
	Ticketing income	Volume ticketing revenue per capita of each cluster	A
	Reliability	Regularity and punctuality of the public transport service, as well as the total travel time including waiting time at bus stop	B
	Average fare per cluster	Sum of fares between clusters divided by distance between clusters	A
	Number of transshipments by cluster	Number of transshipment operations by cluster	A
	Number of passengers per km	Volume of passengers transported per km of each cluster	B
Accidents	Average cost per km of accidents and per capita	Cost of repairs, damages etc.	B

Table 2 – Indicators for public transport on buses - social dimension

Social dimension			
Domain	Indicator	Description	Data
Level of supply	Spatial coverage index	Quotient of the extent of the network and the geographical area of the urban area, expressed in km/km^2	A
	Number of bus stops/ km	Number of stops per km in the cluster, expressed in stops / km	A
	Day frequency	Number of passes during daytime	A
	Night frequency	Number of passes during the night	A
Quality of service	Users satisfaction	Survey within small samples reflecting the average overall satisfaction level	B
	Public service posts	Number of posts by urban area	A
	Stops adapted to people with reduced mobility	Ratio between the number of stops adapted to disable people and the total number of stops per urban area	A
Accessibility	Bus and low floor with ramp	Ratio between the number of low-floor bus ramp and the total number of operating in crowded bus	A
	Security-related crime	Survey within small samples reflecting the average level of satisfaction about the safety felled from users	B
Perception of safety	Comfort and safety of circulation	Survey within small samples reflecting the average level of satisfaction regarding comfort and safety related to road traffic	B
Road safety	Victims of road accidents	Number of road accident victims	B

Table 3 - Indicators for public transport on buses - environmental dimension

Environmental dimension			
Domain	Indicator	Description	Data
Pollutant emissions	Particle emissions	Level of particle emissions per km of each cluster	B
	CO emissions	Level of CO emissions per km of each cluster	B
	Noise emissions in circulation	Average level of noise emissions from bus to operate within each cluster during movement	B
	Noise emissions at bus stops	Average level of noise emissions from bus to operate within each cluster at bus stops	B
	Type of vehicles in circulation	% electric vehicles,% of gas vehicles,% of diesel vehicles	A
Landscape framework	Bus stops in green spaces	Number of bus stops per cluster per km	A

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Table 1 - Indicators for public transport on buses – institutional dimension

Institutional dimension			
Domain	Indicator	Description	Data
Efficiency	BUS routes	Number of km of roads per km of bus line	A
Investment	Promotion and facilitation of public transport	% of taxes (traffic, parking, etc.). allocated	C
	Places for bus stops	% of bus stops at appropriate points determined by origin-destination matrices for each cluster	B
Service	Public transport shelter quality	% of bus stops without signaling; % with signaling%,% with shelter	A
	Quality transshipment points	% of bus stopping places where transshipment have adequate infrastructure	A
	Information	Quality and update of the information provided in transshipment points	A
	Modal interfaces	Number of links present in the modal transshipment point	A
	Social fares	Disadvantaged social groups that benefit from measures to support the use of public transport	B
Equity	Campaigns	Number of promotion campaigns of public transport per year	A
Promotion	Restriction of the use of individual transport	Number of measures to control the supply of individual transport within urban areas	B

From all these proposed indicators, only those with available data should be used in practical applications, regardless of the loss of some information but always preserving the minimum relevant information for each of the dimensions of sustainability.

4. Model for assessing the sustainability of the bus service in midsized municipalities

The model consists in a multi-criteria analysis where two levels of weighting are proposed: one for the four dimensions of sustainability and another for each indicator, corresponding to a more subjective and an objective way of weighting, respectively.

Firstly, the four dimensions of sustainability are weighted from 1 to 5, with 1 being least important and 5 most important in the achievement of sustainable development at an urban area. This weighting should result from inquiries to a specific group of stakeholders, such as politicians, local technicians and experts on public transport services, to obtain and integrate different views and relative importance assumptions with respect to the sustainability dimensions.

Secondly, each indicator is weighted with a nominal scale of (-1), (0) and (1). Positive values represent a alignment with the natural tendency of an indicator in relation to pre-established goal. The inverse applies for negative values. The null value means that the indicator is not distinctive, and presents a value close to the average for the different urban areas under study.

According to Litman [7], the number of indicators included in the mobility survey should allow an adequate assessment considering the size of the sample, viability and validity of data collected for each indicator. Table 5 presents an example of the evaluation of the social dimension for four urban areas (A, B, C and D) where three indicators S1, S2 and S3 were used with a weight of 2, 4 and 1, respectively.

Table 2 - Example application of the model

Urban Area	Dimension		Social	Weight		1	Result
	Weight	2	Weight	4	Weight	1	
	S1Indicator		S2 Indicator		S3 Indicator		
A	100	0	240	1	6.25	0	4
B	75	-1	180	0	9	1	-1
C	25	-1	90	-1	7	1	-5
D	200	1	210	1	2.75	-1	5
Mean	100		180		6.25		

This type of analysis enables to vary the weight, either regarding the sustainability dimension or the indicators according to the stakeholders' perception, sensibility and goals. This process would be repeated for all dimensions. Based on this type of analyses, it is possible to identify areas of intervention for which investment or improvement policies should be directed, thus helping the political class and giving some guidance to the decision-making process.

The level of subjectivity can be reduced or even eliminated when the indicators are represented by functions, such as fuzzy functions where the impact factor varies according to the behavior of the variable, as can be seen in multi-criteria analyses proposed in a multi-dimensional evaluation model of quality of life in University Campus [13] and on GIS-based multi-criteria models for the evaluation of territorial accessibility [14].

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5. Model application to evaluate sustainability of the bus service

The described model was applied to evaluate the level of sustainability of a public transport system of the municipality of Marco de Canaveses.

This midsized municipality has three main urban areas, namely the cities of Marco de Canaveses, Vila Boa do Bispo and Alpendorada-Matos.

The principal public transport in the municipality is ensured by buses, with only one private operator - Joalto, which has its operation center located in the city centre of Marco de Canaveses.

For the three urban areas, all indicators presented on Tables 1 to 4 were evaluated, related to each dimension of sustainability. It should be noted that only some indicators were used in the final assessment of the level of sustainability of public transport, due to the missing data for some indicators. In Table 6 is presented an example of this task, for the indicator "bus spatial rate coverage" that was considered a social indicator.

Table 3 – Spatial rate coverage (radius of 250m)

Urban area	Area (km2)	Coverage area (km2)	Rate (%)	Score
Marco de Canaveses	3,3697	1,0709	31,78	-1
Vila Boa do Bispo	1,4161	0,7711	54,45	+1
Alpendorada e Matos	1,5885	0,8198	51,61	+1
Average			45,94	

The evaluation model was applied considering two types of stakeholders, the local technicians and politicians, which were invited to attribute weights for all indicators and for the four dimensions of sustainability.

In fact, other stakeholders could also have been chosen, such as experts on public transportation, passengers and operators, among others. However, this work also had the goal of comparing two groups of stakeholders that are directly involved in the decision-making process and that is why these were considered. Nevertheless, this is one aspect to explore in future applications of this model.

Since the number of indicators is not equal for each dimension, an average score was determined considering the total number of indicators within each dimension, ensuring an equitable representation of all dimensions in the final score.

On the other hand, assigning different weights to the dimensions of sustainability seems inadequate to the concept of sustainability, mainly in terms of equity between dimensions. This fact could also introduce a high multiplicative weight, which would cause strong deviations on the overall scores. For this reason, it was decided to eliminate this variability by assigning a weight of 1 to each dimension. The results of this procedure are presented in Table 7.

Table 4 - Model application in urban areas of the municipality of Marco de Canaveses

Dimension	Indicator	Technicians				Politicians			
		Average of evaluation	Marco	V.B. Bispo	Alpendorada	Evaluation	Marco	V.B. Bispo	Alpendorada
Social	Spatial coverage rate	4,5	-1	+1	+1	5	-1	+1	+1
	Bus stops per km	3	-1	1	0	3	-1	1	0
	Daytime frequency	4,5	+1	+1	-1	5	+1	+1	-1
	Users satisfaction	4,5	-1	0	0	4	-1	0	0
	Public service posts	3	0	-1	-1	4	0	-1	-1
	Social score		-1,5	0,8	-0,6		-1,4	1,8	-0,8
Environmental	Particle emissions	5	-1	0	1	5	-1	0	1
	CO emissions	5	-1	0	1	5	-1	0	1
	Bus stops in green spaces	4	-1	1	0	4	-1	1	0
	Environmental score		-4,7	1,3	3,3		-4,7	1,3	3,3
Economic	Course average speed	4	-1	0	1	4	-1	0	1
	Energy cost per inhabitant	4,5	-1	0	1	5	-1	0	1
	Reliability	5	1	-1	0	4	1	-1	0
	Average fare per cluster	4,5	1	-1	-1	4	1	-1	-1
	Economic score		0,3	-2,3	1		-0,2	-2	1,2
Institutional	Public transport shelter quality	3	1	1	-1	5	1	1	-1
	Quality transshipment points	3	1	-1	-1	5	1	-1	-1
	Institutional score		3	0	-3		5	0	-5
Weighted final score			-2,9	0,8	0,7		-1,3	1,1	-1,2
Weighted final score without institutional dimension			-5,9	0,8	3,7		-6,3	1,1	3,8

From the results it can be concluded that Marco assumes the title of the less sustainable urban area in relation to public transport. Considering or not the institutional dimension, the relative ranking remains constant either with the evaluation made by politicians or technicians. However, the ranking resulting from the institutional dimension is the complete opposite when considering all dimensions simultaneously.

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6. Conclusions

This paper focused on the integration of all dimensions of sustainability on the evaluation of services and infrastructures related to some branch of the urban mobility, such as the bus system. The institutional dimension associated with the role municipalities play in the functioning and regulation of all sectors of the transportation system must always be incorporated on the assessment of sustainability. In this work were only considered those stakeholders with capacity to directly intervene in the decision-making process at local level, such as the technical staff and politicians. The case study showed that the model can identify the level of sustainability that the bus system has in different urban areas of a municipality and allowed to identify the dimension that most contributed to the final score. This has facilitated the definition of objectives and priority levels of intervention in the public transport system in the municipality of Marco de Canaveses.

Future analyses could include other indicators, as well as an integration in multi-criteria analysis of fuzzy functions in order to reduce the subjectivity and provide a continuous differentiation between different urban areas according to the relative value of the indicators instead of the use of the (-1), (0) and (+1) scale. The weighting of different indicators and dimensions of sustainability should also include other stakeholders, such as experts on different modes of transport, users, residents, traders and others. However, the introduction of instructional participation in this process can already be considered a step forward in the achievement of sustainability in urban areas.

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