SUSTAINABLE MOBILITY EVALUATION IN URBAN AREAS

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Abstract. This work applies the sustainable evaluation to the case of transport and land use planning in urban areas. A set of indicators according the three dimensions of sustainability, environment, economics, and social aspects, are defined to evaluate the mobility in urban areas. The aim of this work is to present a procedure to define a Sustainable Mobility Index in Urban Areas. A system of transports and land use indicators was proposed and used in a Multi-criteria Analysis to define the Index. Based on the Multi-criteria Analysis the indicators priority was defined by a group of specialists in urban and transport planning.

1. Introduction

The search for the sustainability in the cities includes the knowledge of the interaction between the several activities developed in the cities and its impacts in the environment, in the society and in the urban economy. At first, the concern is related to reduce the environmental impacts, even so it is important to observe that the implementation of some measures that minimize the environmental problems can produce negative impacts in the urban economy, and consequently in the population life conditions. Therefore, the main difficulty in urban areas is the implementation of measures that can reduce the environmental problems and should maintain a reasonable urban economy. In this aspect, the transports system is very important for the maintenance of the urban economy but produce some negative environmental impacts. For that it is important to associate the characteristics of the urban development with an adequate sustainable mobility.

The sustainable development is usually seen inside three main dimensions: Environment, Society and Economy; which cannot be analyzed independently. For each one of these dimensions some basic impacts can be identified and related to transports systems:

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- in the environment context: the air, noise and water pollution and natural resources consumption;
- in the social context: health, equality and justness of opportunities;
- in the economic context: regional and urban economy, transports cost, competitiveness and subsidies.

The sustainable mobility is one of the components for a sustainable development of a city and can be achieved by measures that facilitate the population displacement in order to improve the quality of live and promoting efficient consumption of natural resources. In order to evaluating sustainable mobility it is necessary to define an evaluation methodology based on transports system and land use indicators aimed at sustainability urban development. Hence, it was developed a research to identify some relevant indicators to use in a Sustainable Mobility Index. Then an index was defined using a Multi criteria Analysis, and the importance of the different indicators was defined by a group of specialists in urban and transport planning.

2. The Sustainable Mobility

An integrated urban planning and transports system can develop the implementation of structures in which ecological, social and economic sustainability can be reached. The integration of measures in land use planning and transports system can contribute to a better urban sustainability by the implementation of a sustainable mobility.

Erl &Feber [1] consider that the sustainable mobility can be achieved considering the following chain of goals/actions:

- Improve accessibility and the use of the space;
- Increase the environment-friendly modes share (public transport, cycling, walking);
- Reduce congestion;
- Improve safety;
- Reduce air pollution, noise, and visual nuisance.

while

- Developing and maintaining a wealthy and healthy urban economy;
- Ensuring social equity and transport opportunities for all community sectors.

In the development of the referred work it was considered that the sustainable mobility is a mobility way that promotes an equality of possibilities in transport, with access to all the activities in the urban area and contributes to reduce the energy consumption in transports. Consequently, promotes a reduction of the environmental pollution and improves the efficiency of the natural resources applied in transports. This means, in a general way, a promotion to reduce the private vehicle use adopting measures that facilitate

and increase the access of the population to the activities by public transports, walking and biking.

3. Methodology

It was observed in some projects (Lautso *et al.* [2], TRANSPLUS [4] and PROSPECT [3]) the development of case studies in some European cities. Those case studies present some successful examples connecting measures in land use planning and transports system. The measures implemented vary in conformity with each city politics and characteristics. In several cities some indicators were used for monitoring and analyzing how the adopted measures seek the urban sustainability.

A methodology to define a Sustainable Mobility Index will be proposed to evaluate the sustainable mobility level in an urban area, and to compare with others. The following stages will be applied to obtain the refereed Index:

First stage - Proposal of an hierarchical structure of Indicators integrating evaluation of transport system and land use;

Second Stage - A method to define a Sustainable Mobility Index according a Multi-criteria analysis;

Third stage – In an Urban Area to evaluate the Indicators and apply the method proposed to obtain the Index.

According the proposed stages it was developed a system of sustainable mobility indicators. After identifying some relevant indicators they were distributed in different Themes, related with sustainable mobility objectives. According the Multi-criteria Analysis the Themes defines the first level of analysis, and represents a synthesis of the associated indicators, the second level. The main sustainable mobility objectives identified were: increase the use of public transports and more walking and cycling trips; integrate the transport policies and the land use planning; improve the environmental quality; reduce the use of private vehicle trips; and, to promote the urban economy.

Five Themes were proposed:

- Promotion public transports, that seeks land use planning and transport policies to encourage the use of the public transports;

- Promotion of non-motorized modes, that seeks land use strategies to encourage walking and cycling, and hence, reduce the use of cars;

- Environmental comfort and safety, that seeks land use planning and transport policies to increase pedestrians and cyclists safety and enhanced environmental quality;

- Joining transport systems and urban economy, that seeks to promote the urban economy by adopting better transports policies;

- Intensity of private vehicle use, that seeks to identify the type and intensity of private vehicle use in the region.

The Themes and Indicators proposed are presented in Table 1. The third column of the table presents the influence of the indicator in the Sustainable Urban Mobility, (+) if the increase of the indicator promotes a higher urban sustainability or (-) otherwise, the decrease of the indicator promotes a higher urban sustainability. So, the Indicators with (+) must be reinforced and the others must be reduced.

To define the Sustainable Mobility Index, according a Multi-criteria analysis, it is necessary to attribute weight for each indicator and theme. The weights can be generated by a pairwise comparison matrix for the themes and for each group of indicators. The weights are produced by means of the principal eigenvector of the pairwise comparison matrix Saaty [5].

A group of specialists, in urban and transport planning, have been inquired to define the several pairwise comparison matrixes to the Themes and Indicators present in Table 1. The weights obtained to those Indicators and Themes are also present in Table 1, between parentheses.

The Sustainable Mobility Index (MSI) can be obtained from the following equation:

$$\text{MSI} = \sum_{t=1}^{m} w_t \left(\sum_{i=1}^{n_t} a_i w_i v_i \right)$$

a_i: 1 or -1, that depends on Indicator i influence in Sustainable Mobility;
w_i: Indicator i weight;
v_i: Normalized value obtained by the Indicator i in the Study Area;
w_t: Theme t weight;
n_t: number of Indicator of the Theme t;
m: number of Themes.

The procedure to determine the Index has for objective to obtain in a unique value (MSI) the aggregation of the Indicators evaluation. The Indicators aggregation is made using the Weighted Linear Combination (Voogd [6]).

Themes (weight)	Indicators (weight)	Influence
Promotion of Public Transportation (0.26)	Urban Public Transportation supply (0.28)	+
	Frequency of Urban Public Transportation supply (0.22)	+
	Urban Public Transportation (UPT) supply for mobility impaired (0.19)	+
	Average UPT travel time to central city (0.13)	-
	Resident population distance less than 500m from UPT stations (0.18)	+
Promotion of non-motorized modes (0.25)	Resident population distance less than 500m from public green areas (0.09)	+
	Proportion of total area of commercial land use (mixed use) (0.10)	+
	Diversity of commercials and services land used within a 500m square area (0.13)	+
	Length of the network for biking (0.13)	+
	Mean distance to schools (0.26)	-
	Number of retail stores per total land consumption (0.11)	+
	Resident population living on distance less than 500m from roads with predominance of commercials and service land uses (0.18)	+
Environmental Comfort and Safety (0.29)	Total length of roads with *traffic calming measures* (0.11)	+
	Proportion of the UPT moved by clean energy (0.08)	+
	Proportion of roads with sidewalks (0.22)	+
	Numbers of accidents per 1000 residents involving pedestrians/cyclists (0.31)	-
	Proportion of intersection street with pedestrian crossings (0.21)	+
	Proportion of trucks moved by clean energy (0.07)	+
Joining transport systems and urban economy (0.11)	Mean travel cost by using public transportation to city centre (0.29)	-
	Average population income / monthly expenditure using public transportation (0.38)	+
	Adequate loading / unloading places on the street (0.07)	+
	Mean UPT travel time / Mean car travel time (0.26)	+
Intensity of use of private vehicles (0.09)	Number of private vehicle-trip /total length of main transportation road (0.14)	-
	Number of private vehicles-trip /per capita (0.19)	-
	Car travel demand (0.26)	-
	Daily congestion hours expended on the main roads that cross the region or are near it (0.41)	-

Table 1. Sustainable Urban Mobility Themes and Indicators.

4. Conclusion

From the methodology presented stands out that the final value of the Index will depend on the quantification of the Indicators involved in the analysis of an urban area, or areas. However, in some cases not whole the Indicators proposed can be evaluated. So, in that case should be identify the relevant Indicator for the region and identify the Indicator not possible to be evaluated.

Also, using Geographical Information Systems, it will be possible to represent the spatial distribution of the Index in a urban area, or only some Indicators. The cartographic representation of the Index, or the Indicators, will permit to identify spatial differences and to enhance areas that need specific measures to mitigate the identified weaknesses and promote a better Sustainable Mobility.

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