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Prioritization by consensus of enhancements for sustainable mobility in urban areas

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ABSTRACT

Nowadays the European cities usually present important problems at economic, social and environmental levels. The European Union has published policies to ease this issue, and several European cities are creating sustainable mobility urban plans with the measures which can be taken to improve the mobility system. Transport decisions have direct impact on transit times, urban connectivity, and have also effects in the environment, public health and society. Choosing the best enhancement to implement is a complex decision, depending on tangible and intangible criteria, which have to be taken into account together. A compromise solution that weighs travel quality, cost and sustainability inputs has to be achieved. This research work presents a decision support system to select the optimal sustainability enhancement integrating the Delphi technique with the analytic hierarchy process and the VIKOR method.

1. Introduction

During the last decades the European cities have been suffering an important transformation. They have evolved from a multifunctional compact city center to a broad physiognomy center with uses aggregated in specialized zones. This transformation has produced important problems at economic, social and environmental levels (Curiel-Esparza et al., 2004). This new morphology increases mobility operations (Schauer, 2011). The cities have become hotspots of activities, becoming the main drivers of greenhouse gas emissions. Ground transportation is a key factor in the energy consumed, 19% of the global energy demand and 23% of the CO_2 emissions (Gosse and Clarens, 2013). Therefore, any transport enhancement is a crucial political decision as it has direct impact on urban society, changing transit times and urban connectivity. In addition, urban sprawl is not only determinant in traffic, but has also effects in the environment, public health and society (Creutzig et al., 2012). The cities grow at a frantic level (Matthews, 2013), which implies traffic-related delays in almost all of the world's urban centers, while the carbon emissions from ground transportation are growing more and more. In 2013, the European Environment Agency (EEA) report focused on urban transport pointed out that more than 74% of the EU-27 population was living in urban areas (EEA, 2013). According to this report, 50% of the EU's city dwellers were exposed to traffic noise levels above 55 dB. And between 2009 and 2011, up to 96% of urban population was exposed to fine particulate matter ($PM_{2.5}$) concentrations and up to 98% was exposed to O_3 concentrations above World Health Organization recommended levels. The EEA has estimated that the contribution of urban traffic to PM_{10} concentration is 35% while it is up to 64% in the case of NO_2 concentrations (EEA, 2012). The last report of the EEA related to air quality in Europe states that the transport sector is the largest contributor to NO_X emissions, accounting for 46% of total EU-28 emissions in 2012 (EEA, 2014a). In the same report, it is stated that the transport sector has reduced its CO emissions significantly (61% from 2003 to 2012) while the new car sold in 2013 was almost 10% more efficient than in 2010 and the CO_2 emissions decreased from 132 to 127 g between 2012 and 2013 (EEA, 2014b).

In this context, the European Union approved in 2007 a Green Paper on Urban Mobility 'Toward a new culture for urban mobility' (CEC, 2007). This document establishes strategies to fight these

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issues in five different areas that are: against congestion proposes walking and cycling and optimizing the use of private cars; against environmental issues, such as air pollutant emissions and noise suggests the use of new technologies, green procurement, and new ways of driving, also known as eco driving; for improving the efficiency of the transport system gives ideas about the use of intelligent transport systems; to enhance the accessibility to the urban transport infrastructure suggest that the collective transport meets citizen needs, the use of innovative solutions, and the coordination of land use and an integrated approach; and finally, enhancing safety and security of the transport proposing safer behavior, safer and secure infrastructures and safer vehicles. These European Directives have generated national laws. The Spanish Strategy of Sustainable Mobility (Spanish Government, 2009) establishes the most important actions to be accomplished in order to develop the transport system. This policy introduces the concept of the Sustainable Mobility Urban Plan, a tool which points out all the measures which can be developed to improve the mobility system. These mobility plans take into account all the means of transport simultaneously, considering also the sustainable component which adds the value of the triple bottom line that includes economic, social and environmental factors (Canto-Perello et al., 2015; Cunha et al., 2015).

The ground transportation means, from walking to motor vehicles, have usually been studied in isolation. Few examples of integrated multi-criteria analysis have been published (Berrittella et al., 2008). It is necessary to make an aggregate study of all the means of transport. The focus of this study is not the traffic, it is the mobility. But, mobility is a challenge with interlinked factors such as economic, technologic, social and cultural ones. As stated in the United Nations Conference on Environment and Development (UNCED, 1992), the issues should be studied in local, regional and global scales. An important element of the challenge is the need to achieve consensus among different forms of knowledge and different stakeholders from science and policy. The point of view must be multiple, considering the motor vehicles drivers as well as the public transport passengers, cyclists and pedestrians, all of them with different necessities and interests (Katoshevski-Cavari et al., 2010; Orecchini et al., 2011).

The sustainable mobility is a complex problem which has to be considered as a whole. Decisions should integrate simultaneously all the relevant stakeholders, with different interests, some of them opposed to each other, and with different criteria which have to be consensuated. Moreover, some of these criteria are tangible, such as cost and time of travel, whereas some of them are intangible, such as comfort and health. A structured decision-making procedure able to deal with tangible and intangible criteria must be developed in order to reach a consensus in selecting which project is most suitable (Vermote et al., 2014; Wehn et al., 2015). This research work presents a decision support system to select the optimal alternative in terms of sustainable mobility. The hybrid model proposed is an integration of the Delphi technique, the analytic hierarchy process (AHP) and the VIKOR method.

2. Methodology

The Delphi method is an experts' foresight process (Hsu and Sandord, 2007; Ma et al., 2011). It is suitable for building consensus using a series of questionnaires. The method gathers data from a panel of selected experts as the information will be more credible than that of a single expert (Marchais-Roubelat and Roubelat, 2011). This technique improves the efficiency of the dynamic process of the panel of experts.

The AHP method is based on paired comparison judgments of knowledgeable experts (Saaty, 2012). The goal is assessed through a hierarchical structure of several levels. The measurement of the intangibles is the key factor for choosing this method. The use of the AHP methodology in a wide variety of decision-making areas (Canto-Perello et al., 2013; Curiel-Esparza and Canto-Perello, 2013; Martin-Utrillas et al., 2015a) suggests the suitability of this method for structuring relevant knowledge concerning consensus in complex multicriteria problems (Syamsuddin and Hwang, 2010). These comparisons are used to obtain the relative priority of the different criteria in terms of sustainable mobility and to assess the alternatives. In addition, AHP analyzes the consistency of the experts' judgments.

The VIKOR method helps to obtain consensus solutions in compromised problems which involve conflicting criteria. Two parameters will be found for each of the enhancements: utility of the majority, and individual reject. These parameters will be merged in a consensus basis, obtaining the best solution according to this method. The best enhancement is the one which provides maximum utility and minimum regret. This method has been tested in different fields with good results (Martin-Utrillas et al., 2015b; Curiel-Esparza et al., 2014).

3. First questionnaire and decision hierarchy structure

The first step in the process is the analysis of the criteria and the mobility enhancements. Although there is disagreement in the optimum number of panelists, there is certain consensus in the literature that the number must be between eight and twelve experts per panel (Okoli and Pawlowski, 2004; Novakowski and Wellar, 2008; Alvarez et al., 2015). Some experts consider that a small panel is enough when the solutions are achieved through consensus as in our case (Richey et al., 1985). The panel consists of ten experts with recognized competence and knowledge in the field of transport, urban planning and environmental engineering. An anonymous questionnaire is sent to the panel of experts, who answer it adding new alternatives or criteria they think are pertinent to the problem. This information is aggregated and resend to the experts, who reconsider their answers and the ones provided by their colleagues. The criteria and alternatives which are considered less important are removed, as too many elements to compare simultaneously generate confusion in the panelist (Saaty and Ozdemir, 2003). This feedback process defines the hierarchy structure, generated by consensus among the panelists. The panel of experts chose as the main criteria the cost of the enhancement, travel quality and sustainability. These criteria are also divided into subcriteria layered in the hierarchy, so that it is meaningful to compare them among themselves in relation to the element of the upper level (Saaty and Sagir, 2012). The criteria and subcriteria considered when determining the best solution in terms of sustainable mobility are:

- Economy (E). The amount of investment required for the implementation of the enhancement is considered as an inexcusable criterion (Martin-Utrillas et al., 2015c). Can be divided in three subcategories.
  - Initial costs (INI). The initial investment needed to develop the solution.
  - Operation (OPE). The amount of money needed to operate and maintain the solution.
  - Environmental (ENV). This subcriterion takes into account the life-cycle costs of the enhancement. Its importance has been shown before (Chester and Horvath, 2012).
- Travel quality (Q). This criterion engulfs the parameters associated with the means of transport. It is divided in three categories:
  - Time (TIM). Time is a key factor in the mobility, and can be critical to certain stakeholders (Morris and Guerra, 2015;