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Multi-criteria impacts assessment for ranking highway projects in Northwest Spain

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ABSTRACT

This paper presents a multi-criteria model to rank highway projects by predicting their combined potential impact on regional population, economy, environment, territory and mobility. A detailed study of initial conditions enable the selection of functional units of study and the identification of homogenous units within the region, playing a relevant role into the process. Ranking is based on the achievement of both efficiency and cohesion objectives at a regional level. The model is tested by analyzing the Spanish Transport Infrastructure Master Plan (PEIT) for the non-central area of Northwest Spain. Application of impact assessment shows that the construction of infrastructures has selective effects in the area according to the homogenous groups. Potential development was boosted in one of the zone groups, whereas in others, at best, there was a reduction in their regressive tendency. Finally, the model is a dynamic support tool that could be adapted to several planning policies only when the ranking criterion is well-justified.

1. Introduction

When considering a new transport plan or policy infrastructural objectives and demands should be clearly defined. Attending to these requirements, new proposals and sets of alternatives arise. Infrastructure, however, has to fulfil further requirements, such as the value for money, physical constraints, and environmental standards. In this sense, Cost-Benefit Analysis (CBA) is the most widely used method for prioritising and selecting transport projects among alternatives, as in the case of the EUNET Fourth Framework RTD project (Bristow and Nellthorp, 2000) and Environmental Impact Assessment (EIA) is very common and compulsory for most of the transportation projects.

Having passed the requirements to be approved and included in an Infrastructure Master Plan, some infrastructures are not likely to be implemented after all, especially in times of economic crisis. In this case, a new problem arises, since only the most important infrastructure will be given the initial go-ahead. Considering that these infrastructures have undergone monetary and environmental evaluations, other aspects should be considered, such as social, cultural, technical, political, economic, and environmental factors, in an integrated evaluation into transport planning processes, that normally is based on multi-criteria methods (Beuthe, 2002; Hickman et al., 2012; Shang et al., 2004; Vreeker et al., 2002). Although these

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criteria are increasingly considered in transport assessment, they have been approached solely by accessibility measures (Bröcker et al., 2010; López et al., 2008; Talen and Anselin, 1996).

Multi-Criteria Decision-Making (MCDM) includes two categories of decision-making: based on multiple attributes (MADM), which involves the selection of alternatives according to the significance of the defining attributes; and based on multiple objectives (MODM), which constitutes mathematically programming the achievement of multiple objectives simultaneously (Almeida Ribeiro, 1996; Carlsson and Fullér, 1996; Jankwoski, 1995; and Malczewski, 2006).

There are, therefore, different families of methods that, as highlighted by several authors (Carlsson and Fullér, 1996; Shang et al., 2004; Tsamboulas, 2007), include: outranking approaches, such as ELECTRE; additive methods, such as the linear additive model, the Analytical Hierarchical Process (AHP) and the Multi-Attribute Utility Theory (MAUT); and Multiple Objective Programming, such as the Multi-Objective Lineal Programming (MOLP).

Among the intensive research into MOLP made by Li and Lai (2000), Zimmermann's fuzzy programming approach is presented as an ideal method for obtaining compromise solutions to a multi-objective transportation problem. In order to guarantee non-dominated and balanced solutions, Li and Lai (2000) propose the use of a two-phase approach algorithm based on Zimmermann's programming.

As regards transport planning objectives, the principal procedures and guidelines identify the efficiency and social equity as fundamental goals besides the traditional economic and environmental ones. However, those kinds of analysis for high capacity infrastructures have been developed mainly in international and national evaluations (Bröcker et al., 2010; Camagni, 2009; CEC, 1999; ECMT, 2004; EU, 2007; MF, 2005; López and Monzón, 2010; Tsamboulas, 2007), even though this decision-making process and those objectives are especially significant at a regional level, due to the dispersion effects highways are likely to cause at lower scales.

Moreover, infrastructure effects are especially important in peripheral areas, given that their traditional lack of a well-connected network puts them at a disadvantage in terms of development compared with central areas. In general, peripheral areas still feel the effects of the infrastructures, as happen to Spanish and Portuguese cases (Holl, 2004a and 2004b). However, depending on the level of isolation of the area infrastructures may have no impact or even negative impacts if no other measures are taken simultaneously. Additionally, inside peripheral areas diverse levels of peripherality exist and hence the expected phenomena would depend on them. In fact, according to Funderburg et al. (2010) the effects of highway investment on growth patterns (such as on population and employment) are dependent on identifiable characteristics and context such as the location characteristics, i.e. rapidly growing urban areas, exurban regions or rural areas. As a consequence, understanding the effects of new highway constructions on the regional patterns, and therefore the capacity of prioritising highway projects, is crucial for transportation planners and policy makers.

This article contributes to the literature on transport planning decision-making by developing a decision model which aims to prioritize highway projects through integrated impact evaluations for non-central areas. The qualities of the model are threefold. First, the model takes into consideration social, economic, environmental, spatial and mobility impacts in an integrated evaluation, by choosing and combining indicators for each field. Second, the territorial conditions of the non-central area play a main role within the impact assessment, by establishing an internal categorization of the areas that form the region related to the infrastructure development. And third, the proposed model enables decision-makers to rank highway projects included in a Master Plan in order to select the best implementation order when budgets are limited.

The next section of this paper presents the methodology proposed. This methodology is divided into four steps, from selection of the scale of analysis and data collection to sensitivity analysis. In Section 3 the defined model is put into practice through the application of a Spanish case study that describes the procedure, spatial division and expected results. Section 4 presents the study results and, finally, Section 5 outlines the discussion and main conclusions of the research.

2. Methodology

Ranking highway projects or alternatives is based on the evaluation and quantification of the potential impacts of their construction on the geographical areas under their influence. These areas are characterized in relation to several fields, such as accessibility, population, economy, the environment, territory and mobility. Using the historical relationship between impacts and area development, together with the proposal of a set of indicators, the future impacts of new planned highways can be predicted. Following calculation of the indicators, a multi-criteria model enables to assess a group of alternatives using criteria according to PEIT objectives, efficiency and cohesion. Fig. 1 below outlines the methodology applied in the research process.

2.1. Spatial division

Taking decisions on ranking transport infrastructures requires selection of the scale and unit of analysis. These two choices are essential and usually take place simultaneously at the beginning of the process. The selection of the scale limits the kind of territorial strategies and objectives the decision-makers can use. On the other hand, the unit of analysis determines the information necessary to define the territory and, therefore, the data to be used in impact assessment.