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A new composite decision support framework for strategic and sustainable transport appraisals

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ABSTRACT

This paper concerns the development of a new decision support framework for the appraisal of transport infrastructure projects. In such appraisals there will often be a need for including both conventional transport impacts as well as criteria of a more strategic and/or sustainable character. The proposed framework is based on the use of cost-benefit analysis featuring feasibility risk assessment in combination with multi-criteria decision analysis and is supported by the concept of decision conferencing. The framework is applied for a transport related case study dealing with the complex decision problem of determining the most attractive alternative for a new fixed link between Denmark and Sweden – the so-called HH-connection. Applying the framework to the case study made it possible to address the decision problem from an economic, a strategic, and a sustainable point of view simultaneously. The outcome of the case study demonstrates the decision making framework as a valuable decision support system (DSS), and it is concluded that appraisals of transport projects can be effectively supported by the use of the DSS. Finally, perspectives of the future modelling work are given.

1. Introduction

Addressing sustainability issues is a topic of growing concern when performing appraisals of transport infrastructure projects. In this context a sustainable appraisal is defined as one taking into account the widely known three dimensions of sustainability namely the economic, the social, and the environmental dimensions. Incorporation of the concept of sustainability necessitates the revision of traditional decision making processes, where the generally acknowledged cost-benefit analysis (CBA) is used for systematic quantification and comparison of the various benefits and costs generated by a project (Banister and Berechman, 2000; Leleur, 2000). However, decision making based on CBA is found to be inadequate to incorporate and assess multiple, often conflicting objectives, criteria or attributes like environmental or social issues which are usually intrinsically difficult to quantify (Beukers et al., 2012; Barfod et al., 2011; Mackie and Preston, 1998). For this reason it is necessary to expand the decision making process beyond the consideration of solely economic factors (Barfod, 2012a; Wright et al., 2009; Van Exel et al., 2002). The implementation of such a decision making framework under the multiple criteria will require multi-disciplinary and multi-participatory approaches, especially when there is need for assessing a decision problem from different perspectives such as a sustainability perspective (Banister, 2008).

The methodology of multi-criteria decision analysis (MCDA) has previously been used within transport planning to overcome the above mentioned issue of assessing criteria of a strategic character (Barfod, 2012b; Tsamboulas, 2007; Tsamboulas

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and Mikroudis, 2006; Janic, 2003; Sayers et al., 2003; Vreeker et al., 2002). MCDA, which is based on value measurement using qualitative input from decision-makers, is a widely used methodology for assessing impacts that cannot (or only with difficulties) be assigned with a monetary value or quantified (Edwards et al., 2007; Belton and Stewart, 2002; Keeney and Raiffa, 1993). However, the CBA is a fixed part of infrastructure project evaluations in most countries (Hayashi and Morisugi, 2000; Leleur, 2000). It is therefore necessary to develop a methodology that can comprise both the CBA part and the MCDA part of an evaluation, and present a composite result based on these. Several such attempts have been made through the recent years, and the following only represents a few attempts relevant in this context. The EUNET (2001) approach incorporated the CBA result in terms of a benefit-cost rate (BCR) or net present value (NPV) as an additional criterion in the MCDA, and thereby presented the composite result as relative weight scores. Later the COSIMA approach (Barfod et al., 2011; Salling et al., 2007) made an attempt to 'translate' the MCDA result into CBA 'language' by assigning shadow prices to the criteria, and thereby presented the composite result as total rates of attractiveness. However, the COSIMA approach has later proven difficult to apply in practise due the trade-off considerations that need to be made between the CBA and MCDA parts in order to estimate the shadow prices. More recently an application with some similarities to the EUNET approach – based on including the CBA as an additional criterion in the MCDA – has been made to support the effective implementation of transport policy when prioritising national road infrastructure programmes (Gühnemann et al., 2012).

In this paper a modelling framework is developed taking its basis in the EUNET approach. The framework, however, enhances the CBA-part by introducing the use of feasibility risk assessment (FRA) on the results (Salling and Banister, 2009; Salling, 2008). The scope of the FRA is on the risk that the investment is underestimated and the demand is overestimated which ultimately will produce infeasible economic results. The framework proceeds by examining FRA for the project alternatives one by one, and afterwards the results are used as input as one of the criteria within a set of decision criteria for a MCDA. This way the application of the framework leads to a ranking of the alternatives in order of attractiveness.

Conventional CBA relies on single result values, where all the considerations and calculations are reduced to a single aggregated value such as a NPV or BCR. FRA therefore builds upon the conventional CBA through the adoption of a quantitative risk analysis. Here the probabilities of occurrence of particular risk factors can be incorporated, and decision-makers and analysts can make use of their expertise. The technique used is Monte Carlo simulation which involves a random sampling method (in this case in terms of a Latin Hypercube sampling approach) concerning each different probability distribution selected for the actual model set-up (Vose, 2008). Evidently, input variables such as construction cost estimates, travel time savings, air pollution, accidents savings, etc., are assessed based on various impact, cost and demand models. Current research has however proved that substantial bias and inaccuracy are present within especially two of the input variables, namely the construction costs and demand forecasts which ultimately makes up for the travel time savings (Flyvbjerg et al., 2003; Nicolaisen, 2012). Typically four causes with regard to the inaccuracy present in the construction cost and demand forecast are given, capturing technical, economic, political and psychological aspects (Cantarelli et al., 2010; Flyvbjerg, 2007). The technical explanation is defined as so-called *forecasting errors* which can be boiled down to the fact that models per definition are imprecise. Furthermore, the second cause is rooted in terms of economic incentives which can lead to *deliberate* under- or overestimations. Thirdly, there are the political explanations which are more *strategic misrepresentations* denoted as pessimism bias (Næss et al., 2006) and finally, there are the most well discussed cause namely the psychological explanations which are rooted in *planning fallacy and optimism bias*. Recently, a fifth category of explanation for bias in project evaluation has been referred to as so-called *selection bias* claiming that such bias inevitably occurs whenever ex-ante predictions are related to the decisions on whether to implement a project or not (Eliasson and Fosgerau, 2013).

In order to assess such inaccuracy, Flyvbjerg and COWI (2004) constructed a set of references classes which is a pool of projects similar in scope, size, mode, etc. Such reference class information has been gathered within a large database system containing ex-ante and ex-post information with regard to construction cost and demand forecast inaccuracy. Reference Class Forecasting (RCF) was originally developed to compensate for the type of cognitive bias in human forecasting that Princeton psychologist Daniel Kahneman found in his Nobel prize-winning work on bias in economic forecasting (Kahneman and Tversky, 1979). Evidently, each reference class contains information to be fitted against a probability distribution function entailing information for respectively construction cost over-run and demand forecast under-run, so-called Optimism Bias (Salling and Banister, 2009). From such elaboration of uncertainties an accumulated descending output graph can be derived. This type of graph depicts e.g. the BCR in terms of an interval result instead of the conventional single point estimates.

The framework is developed as a part of the Oresund EcoMobility project, which was a part of EU's Interreg IV A programme. The project is a Swedish–Danish cross-border initiative that unites universities, companies and authorities in an effort to increase competence within climate friendly transport of both goods and people. The EcoMobility (EM) modelling framework thus consists of two parts, namely an Excel-based software model (entitled the EM-DSS) and a customised examination process. In the EM-DSS the conventional CBA calculations as well as the FRA is carried out. Moreover, the DSS contains a toolbox of different MCDA techniques, which can be used depending on the type of decision problem and the composition of the ratifying group doing the assessments. The concept of decision conferencing (Phillips, 2007) is introduced in the examination process in order to formalise and operationalise the group processes that enable the assessments in the DSS. For illustration, the application of the model is presented by a case study considering alternatives for a new fixed link between Helsingør (Elsinore) in Denmark and Helsingborg in Sweden (referred to as the HH-connection). The presented framework moreover serves as the basis for the methodological development of the SUSTAIN project supported by a grant from the Danish Strategic Research Council.