Transport Policy 48 (2016) 67–81

Contents lists available at ScienceDirect

Transport Policy

journal homepage: www.elsevier.com/locate/tranpol

A new evaluation and decision making framework investigating the elimination-by-aspects model in the context of transportation projects' investment choices

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ARTICLE INFO

Article history:
Received 15 April 2015
Received in revised form
16 October 2015
Accepted 19 February 2016
Available online 4 March 2016

JEL classification numbers:
C44
C54
D72
H43
L91
R42

Keywords:
Transportation investment
Collective decision making
Cost benefit analysis
Elimination by aspects
Consensus model/joint decision making
Index of dispersion
Behavioral choice

ABSTRACT

The Transportation Elimination-by-Aspects (TEBA) framework, a new evaluation and decision making framework (and methodology) for large transportation projects, is proposed to elicit, structure and quantify the preferences of stakeholder groups across project alternatives. The decision rule used for group decision making within TEBA is the individual non-compensatory model of choice elimination by aspects (EBA). TEBA is designed to bring out the decision rule employed by decision makers when ranking the options presented, incorporate various criteria types and ease communication of relevant information related to options and criteria for multiple stakeholder groups. It is a platform for democratizing the decision making process. The TEBA framework was tested using a case study investigating alternative land connections between Beirut and Damascus. Key results showed that (1) stakeholders have employed EBA in making decisions, (2) a defined group of decision makers will rank options differently when provided with modified sets of criteria, (3) the public sector and general public groups ranked Impact on Employment among the top criteria, (4) the most important criterion per group from EBA was as expected; (5) the EBA analysis suggested that only 3–4 criteria are significant in reaching a decision; (6) aggregation of user assigned weights masked relative importance of criteria in some cases; and (7) analysis of user assigned weights and Minimum Threshold (MT) values suggest higher risk perception with increased criterion importance. Policy implications include recommendation to reach out to stakeholders for input on decisions, including the "people" but refrain from relying on criteria weights assigned by "experts" and reduce the "experts"' role in decision making. Also, it is recommended to model the decision making in a probabilistic framework rather than a deterministic "one score" approach, seek to identify a consensus ranking, place particular attention on determining the values of the criteria that emerged as "top" at the evaluation stage and continue to emphasize risk measures.

1. Introduction

In recent years, non-physical communication networks have achieved revolutionary progress. Despite that, physical transport of people and goods remains a national and international need, as evidenced by facts such as annual investment in transport infrastructure in the CEE countries typically around 1–2% of GDP (Short and Kopp, 2005) and the UK announcement in 2010 of a 200 billion pounds in investments in infrastructure over the next 5 years (Sassoon, 2010). Transportation investment projects are strategic endeavors with high impacts both at the macro-economic level and at the financial level given their capital intensive nature. Several alternative options are typically identified for any given project (Bristow and Nellthorp, 2000). The options[1] are evaluated by determining a set of criteria for evaluation and assessing the performance of each option with respect to those

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[1] For example, in order to connect 2 points A and B, the options include: different highway routes, different rail routes and technologies, air transport, sea transport. As another example, consider prioritizing independent developments competing for funds; the options in this case could include: a highway project, an urban roads network upgrade, a metro system.

http://dx.doi.org/10.1016/j.tranpol.2016.02.005
0967-070X/

criteria (Adler, 1987). Evaluation of options is a complex task and the reader is referred to Adler (1987), de Palma et al. (2007) and de Palma et al. (2013) for details. A preferred option (or a ranking of available options) is determined based on the results of the evaluation, e.g. Cost Benefit Analysis (CBA) (Small, 1998). The decision making model that governs this latter step in the process has been insufficiently researched (Sayers, Jessop and Hills 2003, Priemus and Bert, 2007). Moreover, fit-for-purpose criteria and risk measures, accounting for multiple stakeholder views, as well as ability for synthesizing a decision from multiple groups' decisions remain challenges within the current process despite work by de Palma et al. (2009), Berechman (2009), Salling and Banister (2009), etc. The purpose of this paper is to address some of these issues: We propose an evaluation and decision making framework to elicit, structure and quantify the preferences of stakeholder groups across project alternatives.

The most common decision making methods are CBA, when only monetizable criteria are considered, and/or some form of Multi-Criteria Decision Analysis (MCDA) procedure. The MCDA methods reported to have the most success include Linear Additive Models (Keeney and Raiffa, 1976), Analytical Hierarchical Process (AHP) (Saaty, 1980) and multi-attribute utility theory (MAUT) (Sayers et al., 2003, Quinet, 2000). The generally applied paradigm in the literature and in practice is clearly one of relative weighing and arithmetic aggregation (Tsamboulas, 2007; Sayers et al., 2003). Some of the key issues that were highlighted with such approaches include inconsistency and lack of transparency in understanding the underlying logic leading to a decision i.e. the decision rule and preferences amongst the criteria used in reaching the decision as well as the rank reversal phenomenon (DTLR; Wang and Luo, 2009). Additional challenges to a wider application of the more popular linear additive and analytical hierarchy models in the context of transportation investment project selection include the need for alternatives to be settled in weak preference relation, the need for any two parameters to be in a constant relative compensation and the need for basic parameters to be monotonous (Cundric et al., 2008).

The DEX model (Cundric et al., 2008) and the work by Nellthorp and Mackie (Nellthorp and Mackie, 2000) are noted attempts to overcome these challenges. However, the DEX falls short in responding to several critics such as its low sensitivity to small differences between alternatives and weakened transparency and increased effort in dealing with larger numbers of options and Nelthorp and Mackie's model does not deal with the aggregation of preferences.

Based on our review of the latest attempts at improving decision making frameworks, our understanding of the key characteristics required in a decision model for transportation investments decision making, and our understanding of the Elimination By Aspects (EBA) model characteristics and methods described in more detail in Section 2, this paper presents the Transportation Elimination-by-Aspects (TEBA) framework, a new evaluation and decision making framework (and methodology) for large transportation projects. TEBA is not an attempt to replace CBA, but rather takes CBA a step forward. While CBA does not indicate how multi-dimensional preferences may be aggregated, this research proposes one way to do so with TEBA. TEBA is proposed to elicit, structure and quantify the preferences of stakeholder groups across project alternatives. The decision rule used for group decision making within TEBA is the individual non-compensatory model of choice EBA. TEBA is designed to bring out the decision rule employed by decision makers when ranking the options presented, incorporate various criteria types and ease communication of relevant information related to options and criteria for multiple stakeholder groups. It is a platform for democratizing the decision making process. The TEBA framework is tested using a case study investigating alternative land connections between Beirut and Damascus. The case study is used to analyze and compare, across three key stakeholder groups including the Public Sector, the Private Sector and the General Public groups (i) options rankings, (ii) criteria preferences, and (iii) a consensus ranking of options.

The next section elaborates on the EBA model. Section 3 describes the TEBA framework. Section 4 presents a case study application of the TEBA framework and walks the reader through details of TEBA implementation as well as results from that case study. Section 5 concludes with key insights, contributions and policy implications.

2. The elimination-by-aspects model

The elimination by aspects model discussed here offers a non-compensatory probabilistic alternative to existing decision models of choice. Non-compensatory models are very important, and have received very little attention in Transportation. Our approach:

1. uses the concept of minimally acceptable levels of attributes proposed by Simon (1955) and Young (1984),
2. uses a lexicographic approach to decision making while relaxing the requirements of *a priori* ordering of alternatives,
3. generalizes the choice model of Luce (1959) whenever the alternatives are composed of disjoint aspects, and
4. generalizes the choice model of Restle (1961), who developed the representation of choice alternatives as collections of measurable aspects, whenever only binary choice probabilities are considered (see Tversky, 1972a, 1972b; Ranyard, 1976).

Tversky introduced EBA as "a probabilistic theory of choice, based on a covert elimination process, which accounts for observed dependencies among alternatives". It is a non-compensatory model that adopts an elimination approach to alternatives that do not meet satisfaction level of a selected aspect, starting with the most important aspects and proceeding recursively (Tversky, 1972a, 1972b).

EBA belongs to the family of discrete choice models in that it defines a probability for the choice among available alternatives. Its decision rule is a combination of lexicographic and satisfaction rules (see the early presentations in Ben-Akiva and Lerman, 1985 and Anderson et al., 1992). EBA has typically been employed as a descriptive model of choice mostly popular in marketing and psychology (Fader and McAlister, 1990; Wickelmaier and Schmid, 2004; Laurent, 2006) but has also been used in other contexts such as transportation demand analysis and residential choice (Kato and Kosuda, 2008; Young, 1984). Applications of EBA as a prescriptive model exist as well (Gati and Fassa, 1995).

For every experiment, the process starts with a clear identification of alternatives and criteria. An alternative is a viable option that the decision maker can choose; e.g. a toll highway vs a high speed railway connection between points A and B. A criterion is a measure by which an alternative may be judged; e.g. Net Present Value (NPV) or travel time. The next step is to evaluate/analyze each alternative and report the value of each criterion for each alternative in a performance matrix. For criteria that are quantifiable, a Minimum Threshold (MT) is set based on expert knowledge and is fixed thereafter or alternatively left for each individual to set prior to decision taking. The performance matrix is used as a basis to build the "utilities matrix": When a criterion meets the MT for an option, a utility scale is assigned for that criterion for that alternative; a zero is assigned otherwise. The utility scale represents the importance of a criterion or, more specifically, it determines the probability that the criterion is chosen to guide the