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An MCDA approach for the selection of bike projects based on structuring and appraising activities

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ABSTRACT

This paper presents an MCDA approach for the structuring and appraising activities of a large and complex decision problem. More specifically, the paper makes use of the three-step structuring process for decision analysis proposed by von Winterfeldt and Edwards: (1) identifying the problem; (2) selecting an appropriate analytic approach; and (3) developing a detailed analytic structure. For illustration of the approach a case study dealing with the assessment task of prioritising and selecting initiatives and projects from a public pool with limited funds is examined throughout the paper. The process is embedded in a Decision Support System (DSS) making use of the REMBRANDT technique for pair wise comparisons to determine project rankings. A procedure for limiting the number of pair wise comparisons to be made in the process is in this connection presented. Finally, strengths and weaknesses in the approach are discussed and conclusions are made.

1. Introduction

When making decisions, decision-makers (DMs) will in most cases try to choose the optimal solution. Unfortunately, a true optimal solution only exists if you are considering a single criterion. In most real decision situations, basing a decision solely on one criterion is, however, insufficient. Probably several conflicting and often non-commensurable objectives should be considered. As a result of this it is impossible to find a genuine optimal solution, a solution which is optimal for all DMs under each of the criteria considered (Løken, 2007). Multi-criteria decision making (MCDM) is a generic term for methods that assist people in making decisions using their own preferences in cases where more than one conflicting criterion exists. Using MCDM can be said to be a way of dealing with complex problems by breaking them into smaller pieces. After weighting procedures and judgments of the smaller components the pieces can be reassembled to present an overall picture to the DMs.

Another term used instead of MCDM is Multi-Criteria Decision Analysis (MCDA), where the use of 'analysis' instead of 'making' emphasises that the method should assist the DMs in making decisions (as the method itself cannot make the decision). Hence, the aim of MCDA is to assist the DMs to choose, rank or sort alternatives within a finite set according to two or more criteria so that they feel comfortable with the final decision (Chen et al., 2008). By using MCDA the DMs should feel that all important criteria have been properly accounted for, which should help to reduce the possibility of post-decision regret (Belton and Stewart, 2002). Ideally, the MCDA method will help the DMs to understand and identify the fundamental criteria in the decision problem and avoid making important decisions only out of habit.

Structuring the decision problem – taking it from an initially vague and ill-defined problem to one that can be formulated, modelled and analysed mathematically – is by von Winterfeldt and Fasolo (2009) stated to be the hardest yet most crucial part of an operations research (OR) analysis. This is a focus of decision analysis, where the emphasis of problem structuring is on shaping general statements by the DMs about their goals, concerns, issues and uncertainties and turning these statements into a clear and transparent representation of the decision problem which can be mathematically formalised using the principles of decision theory, see, e.g. von Winterfeldt and Edwards (1986, 2007) and Belton and Stewart (2002).

This paper presents the structuring and appraising activities for the public Danish pool for more bike traffic, which was conducted in late 2009 as consultancy for the Danish Road Directorate. The bike pool is a result of a political agreement concerning a new green profile for traffic planning in Denmark supporting bike projects with 1 billion DKK in the period from 2009 to 2014. As a part of the political agreement 150 million DKK was in 2009 allocated to support initiatives and projects (onwards referred to as projects) that contributes to make bikes a more attractive means of transportation. The aim of the pool was to move users from car traffic, but also public transportation, to bikes. The bike pool was open for applications of widely varying characters, and in principle it was possible for everybody to apply for subsidies from the pool. As a result of this a total of 133 project applications were

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submitted from municipalities, regions, organisations, companies and research institutions. The projects amounted to a total sum of approximately 1 billion DKK, which corresponded to a subsidy sum of approximately 450 million DKK (most projects were eligible for between 30% and 50% subsidy and a few projects for 100% subsidy from the pool). Hence, there was a need for an appraisal of which projects should be given subsidies from the pool, as it was impossible to give subsidies to all the projects. The technical evaluation task was henceforth to design and apply a series of principles and methods which were capable of handling this large quantity of projects in an appropriate and optimal way. This, so that the total means of the pool could be allocated to those projects and initiatives that contributed the most to the overall objective.

In Denmark it is a basic point of view that appraisals of transport projects shall be based on socio-economic evaluation to state if the projects are economically feasible or not. This is normally conducted using a manual for socio-economic appraisal from 2003 (Danish Ministry of Transport, 2003) and the newest edition of traffic economic unit prices (the key figures' catalogue). However, currently no such foundation exists for economic appraisals of bike projects, and moreover it was impossible to conduct impact calculations on the applications submitted due to their vaguely written form and content. As the assessment task went beyond socio-economic calculations and as the limitations of the task (time constraints, budget limitations, etc.) made it impossible to set out a foundation for this, it was decided to use a methodological approach which was based on principles for value measurement different from traditional cost-benefit analysis (CBA). Hence, the concept of MCDA was introduced to deal with the assessment task in order to ensure an appropriate and comprehensive assessment, while at the same time making it possible to perform the appraisal within a limited time frame. Thus a Decision Support System (DSS) named the CPP-DSS (CykelPuljePrioritering (Danish for Bike Pool Priority)) was developed. The DSS was based on a qualitative evaluation, but with a perspective saying that the approach to be applied could be based on a combined use of CBA and MCDA as it is e.g. described by Leleur et al. (2007) and Barfod et al. (2011).

With reference to the previous work on decision analysis conducted by other researchers this paper deals with three main research questions: can the theory of decision analysis be useful to structure a decision problem involving a large number of options, multiple objectives and multiple stakeholders? Can the appraisal of a decision problem using MCDA be operationalised into a DSS that can inform the DMs in terms of both interaction and interpretation of the results? And finally, can a set of appropriate guidelines be formulated for the appraisal of widely varying projects using the DSS?

This paper is organised as follows. After this introduction a literature review on structuring decision problems for OR in general and decision analysis in particular is conducted. In the following three sections a process for structuring and appraising a decision problem is conducted on the case study comprising the three steps of: identifying the problem, selecting an analytical approach and developing a detailed analytical structure. Finally, conclusions are made and perspectives for the future modelling work are given.

2. Problem structuring using decision analysis

At the most basic level a decision analysis structure defines the scope of a decision problem, including the DMs and stakeholders, their values and alternatives, the range of consequences of concern, and the key uncertainties (von Winterfeldt and Fasolo, 2009). Scanning the literature on structuring problems for decision analysis it is found that structuring does not only involve framing the problem, but also two additional steps of selecting an appropriate structure and developing this in details before numerical modelling and analysis begins (von Winterfeldt and Edwards, 1986, 2007; Keeney, 1992; Belton and Stewart, 2002; Goodwin and Wright, 2009). In this respect problem structuring methods (PSM) can be very helpful to support groups in confronting the three steps (Mingers and Rosenhead, 2004).

There is much to be learnt about problem structuring from the body of work stemming from the fields of what is collectively referred to as "soft" OR or PSM, see Rosenhead and Mingers (2001). Under this are among others the following approaches, which pay attention to multiple objectives and multiple perspectives in a more or less formal way: Strategic Options Development and Analysis (SODA) by Eden and Ackermann (2001), and more recently extended to the concept of journey making (Ackermann and Eden, 2001); the Strategic Choice Approach by Friend (2001) and the Soft Systems Methodology (SSM) by Checkland (2001). Each of these methods has something to offer problem structuring for MCDA, see, e.g. Neves et al. (2009) using SSM for structuring a MCDA model.

Phillips (1984, 2007) deals with the concept of a "requisite decision analysis model" which he defines as one that is sufficient in form and content to resolve the issue at hand. Moreover, he states that a decision model is requisite if no new intuitions arise in the group. While requisite modelling can be best recognised when a full model is developed, including elicitation of data, this notion can also be applied to decision analysis structure, implying that there can be structural representations that are simple enough to capture the essence of a decision problem, and no more complicated than necessary to obtain sound insights. A decision analysis structure is thus requisite if no additional insights emerge that will lead to significant additions or modifications of the structure (von Winterfeldt and Fasolo, 2009).

MCDA is deemed to offer a sound methodology for promoting a good decision making process (Keeney and Raiffa, 1993) and the field is characterised by a variety of different techniques and approaches (Stewart and Losa, 2003). A representative excerpt of the literature on decision analysis (von Winterfeldt and Edwards, 1986, 2007; Keeney, 1992; Keeney and Raiffa, 1993; Belton and Stewart, 2002; Goodwin and Wright, 2009) indicates the relevance of distinguishing between the following eight different analytic structures depending on the type of the problem being either a multi-attribute evaluation problem, or a decision problem involving significant uncertainties, or a probabilistic inference problem:

- Evaluation problems.
  - Means-ends networks.
  - Objectives hierarchies.
  - Consequence tables.
- Decision problems under uncertainty.
  - Decision trees.
  - Influence diagrams.
- Probabilistic inference problems.
  - Event trees.
  - Fault trees.
  - Belief networks.

First, almost all problems have multiple objectives and thus some structuring of alternatives and objectives is always useful (Keeney, 1992). Simple objectives hierarchies and consequence tables help to clarify the key relationships between alternatives and objectives. If data concerning consequences are not readily available, ranking projects by objectives can be illuminating. Second, decision trees are useful, if there are clear, important, and discrete events that stand between the implementation of the alternatives and the eventual consequences. Decisions, for example, dealing with major disasters, terrorism, and the like lend themselves to