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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.

***Keywords**:* Decision Analysis, Problem structuring, Multi-Criteria Decision Analysis (MCDA), REMBRANDT, Decision Support Systems (DSS).

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

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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 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 (Eden and Ackermann, 2001), and more recently extended to the concept of journey making (Ackermann and Eden, 2001); the Strategic Choice Approach by Friend and Hickling (Friend, 2001) and the Soft Systems Methodology (SSM) by Checkland (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 decision trees. The multiple consequence part of this type of problem can be handled by listing all consequences at the end of the decision tree and determining an equivalent value or utility through standard multi-attribute utility analysis (Keeney and Raiffa, 1993). Influence diagrams are most useful when some of the uncertain variables are continuous and causally linked. In this case it may be easier to develop a deterministic model that calculates the propagation of causal effects and then to superimpose a probabilistic simulation to assess the overall uncertainties (von Winterfeldt & Edwards, 2007). Multiple objectives aspects can easily be integrated with influence diagrams. Fault trees, event trees, and belief nets are special to inference problems.

Decision trees and diagrams are the major structuring tools of decision analysis. However, building such trees and diagrams can be regarded as a fairly specific activity. In order to deal with the structuring within a broader perspective von Winterfeldt & Edwards (1986, 2007) proposed the following three step procedure for structuring decision problems in a decision analysis: 1) identify the problem, 2) select an analytical approach, and 3) develop a detailed analysis structure. Although these steps seem reasonably distinct, the intellectual work behind them can be extremely recursive. The decision analyst should prepare himself to go through each step several times and probably restructure the problem a number of times.

It can be noted that PSMs structuring allows local, partial solutions rather than global solutions that imply a merging of different views (Mingers and Rosenhead, 2004). This means that values and uncertainties are structured in qualitative incommensurable form and it distinguishes the structuring of PSMs from the structuring activities in decision analysis, which aims at developing a quantitative model of the DMs values (multi-attribute utility problems) and perceptions of uncertainties (uncertainty problems).

In the following sections the three steps of von Winterfeldt and Edwards (1986, 2007) will be applied to the case study of distributing subsidies from the Danish bike pool. The focus is on the process and the techniques applied; the results are the property of the Danish Road

Directorate and will thus not be specified. However, this should not affect the scope of the paper.

3. Identifying the problem

When they are first encountered, some decision problems appear to be overwhelmingly complex. Any attempt at clear thinking can be frustrated by the large number of interrelated elements that are associated with the problem, so that, at best, the unaided DMs can have only an unclear perception of the issues involved (Goodwin and Wright, 2009). Thus, when DMs approach a decision analyst for consultancy with a problem, they will often only have a general idea of what the problem is, and in many cases the initial discussions between the DMs and the decision analyst change the character of the problem.

In identifying the extent of the problem von Winterfeldt and Edwards (1986, 2007) suggest that it is useful to answer five simple questions, see Table 1. For this purpose a preliminary meeting was held with key persons from the Danish Road Directorate in order to answer the questions. In addition to this a literature study was conducted in order to expose previous research within the field of appraisals of bike projects. The questions and their answers are outlined in Table 1.

[Table 1. Questions identifying the problem]

Answering the questions in Table 1 made it clear that the decision problem was of a complex character involving many different stakeholders whose preferences needed to be accounted for in the analysis. Even though the final decision regarding the case study was in the hands of the political parties, government officials from the Road Directorate were to act as DMs for practical reasons.

As previously mentioned, the bike pool is a result of a political agreement concerning a new green profile for traffic planning in Denmark where the aim is to move users from car traffic, but also from public transportation to bikes. The pool was open for projects of a widely varying character, 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 submitted from municipalities, regions, organizations, companies and research institutions. The prerequisites of the applications, which were almost non-existing, resulted in many different types of projects with highly varying impact descriptions. Some applications were well-described and well-defined with regard to expected impacts for the projects, while other applications more or less only consisted of a map with an indication of where to build a bike path. For this reason a division of the projects into different types needed to be made.

4. Selecting an analytical approach

At some stage the emphasis of the analysis needs to move from problem structuring to model building where a specific analytical approach is used for the development of a framework for the appraisal of the projects. Model building should in this context be regarded as a dynamic process, informed by and informing the problem structuring process, and interacting with the process of appraisal. It may involve some iteration, search for new criteria, discarding, reinstating and redefining old ones, and further extensive discussions amongst the participants in the process. Moving from a broad description of the problem, whether it is a simple clustering of ideas, a fully elaborated map, or some other representation of the issue, to a preliminary definition of a model for MCDA, requires a good understanding of the chosen approach to multi-criteria modelling. The nature of the model which is sought will differ according to the nature of the assessment task, whether alternatives are explicitly or implicitly defined, and the particular approach selected for the analysis.

For the bike problem, which can be characterised as a multi-attribute evaluation problem, an initial workshop with the participation of key stakeholders (see Table 1) and DMs was held with the purpose of identifying a set of fundamental objectives, see Keeney (1992). The workshop was set out as a ‘futures workshop’; see e.g. Leleur (2008), where an impartial facilitator led the participants through the three phases of ‘criticising’, ‘fantasising’ and ‘implementing’. By doing this a long list of more or less relevant objectives was identified. However, many of the objectives identified were important as they served other ends objectives. By pursuing the means-ends chain of objectives one will eventually arrive at objectives, whose importance are self evident – these are the fundamental objectives (Keeney, 1992). Interviews or workshops to elicit objectives typically generate many objectives that are not fundamental to the decision problem (Belton and Stewart, 2002). These falls into two categories: means objectives and process objectives (von Winterfeldt and Edwards, 2007). Means objectives can affect fundamental objectives (e.g. air pollution is a means to create health impacts), but are not themselves relevant for the assessment. Process objectives on the other hand are those that refer to the process by which a decision is made rather than its consequences. Stakeholders and DMs expect all objectives to be represented in some form in an assessment. Process objectives, however, should be separated out and considered when designing and implementing the analysis process (Keeney, 1992). During the workshop focus was on eliciting operational objectives. However, checks were subsequently performed on selected test-projects in order to assure that also the criteria of completeness, absence of redundancy and decomposability were met. This led to minor adjustments of the objectives. Table 2 shows the objectives that were elicited at the workshop for the appraisal of bike projects on an overall level. The fundamental objectives are shown in the left column and the selected measures in the right column.

[Table 2. Objectives and measures for evaluating bike projects on an overall level]

Structuring the objectives does not lead directly to a formal analysis. Instead, it clarifies for the DMs and stakeholders how their concerns are being handled. A MCDA method can then be used to summarise the consequences of projects and to aggregate these to a common value metric. Thus, when choosing a MCDA approach, there are many aspects to consider. The most important is to apply an approach that really measures what it is supposed to measure (validity). Different approaches are likely to give different results, so an approach that reflects the DMs' 'true values' in the best possible way should be chosen. In addition the approach should provide the DMs with all the information they need, and it must be compatible with the accessible data (appropriateness). Moreover, the approach must be easy to use and understand (Hobbs and Meier, 2000). If the DMs do not understand what is happening inside the methodology, they will perceive it as a 'black box'. The result of this may be that the DMs do not trust the recommendations from the methodology. In that case it is meaningless to spend time applying the approach. Some guidelines for choosing an appropriate MCDA method can be found in e.g. Guitouni and Martel (1998) or Zopounidis and Doumpos (2002).

The DSS developed for the CPP case was subsequently specified to be based on a value measurement model. Using this approach a numerical score is assigned to each project producing a preference order such that project j is preferred to project k if and only if $V(j) > V(k)$. The various criteria are given weights that represent their partial contribution to the overall score, based on how important the criteria are to the DMs. Ideally, the weights should indicate how much the DMs are willing to accept in the trade-off between two criteria (Keeney and Raiffa, 1993; Belton and Stewart, 2002).

During the previously mentioned workshop the participants expressed the expectation that the assessment technique to be used in the further analysis should be easy to understand both for professionals and non-professionals. Moreover, the judgments to be made should be as simple as possible in order to ensure transparency both in the process, but also when the results afterwards need to be defended. Due to this, the character of the objectives to be measured, and the information level of the projects the CPP-DSS was chosen to be based on a technique using pair wise comparisons for the elicitation of scores and weights. The usefulness of this technique is, in respect of the case study, that the decision problem is decomposed into a hierarchy of more easily comprehended sub-problems, each of which can be analysed independently. The elements of the hierarchy can relate to any aspect of the decision problem – tangible or intangible, carefully measured or roughly estimated, well- or poorly-understood – anything at all that applies to the decision at hand. Once the decision hierarchy is built, the DMs can systematically evaluate its various elements by comparing them to one another two at a time, with respect to their impact on an element above them in the hierarchy. In making the comparisons, the DMs can use concrete data about the elements, or they can use their judgments about the elements' relative meaning and importance. It is the essence of the technique that human judgments, and not just the underlying information, can be used in performing the evaluations.

Thus, the CPP-DSS makes use of the REMBRANDT (Ratio Estimation in Magnitudes or deci-Bells to Rate Alternatives which are Non-Dominated) technique by Lootsma (1988, 1999) which is a multiplicative version of the Analytic Hierarchy Process (AHP) by Saaty (1977, 2001). REMBRANDT proposes to overcome three issues regarding the theory behind AHP, for elaborations of these see Olson et al. (1995), Ramanathan (1997), Lootsma (1999), and van den Honert and Lootsma (2000). The technique makes use of pair wise comparisons between projects to determine subjective impacts under each criterion in the assessment and between criteria in order to determine their relative importance. The DMs pair wise comparative judgment of the projects P_j versus P_k is captured on a category scale to frame the range of possible verbal responses. This is converted into an integer-valued gradation index δ_{jk} according to the REMBRANDT scale in Table 3.

[Table 3. The REMBRANDT scale (van den Honert and Lootsma, 2000)]

Thus there are five major, linguistically distinct categories in Table 3: indifference, weak, definite, strong and very strong. Moreover, there are four so-called threshold categories between them which can be used if the DMs are in-between the neighbouring qualifications. The values obtained by the comparisons are gathered in a comparison matrix and using the principles of the REMBRANDT technique relative project scores are calculated (this procedure is also applied on criteria level). Finally, scores are aggregated by the product of projects relative scores weighted by the power of weights obtained from the analysis of hierarchical elements above the projects. This leads to a final score for each project, which allows a subjective rank ordering of the projects.

It should be noted that the problem could benefit from other MCDA approaches as well. The original AHP could for instance be applied in the same way as the REMBRANDT technique, but outranking procedures, see e.g. Roy & Vanderpooten (1996), could also be an option. The REMBRANDT technique was chosen due to the simplicity and transparency of the pair wise comparisons which are easy to explain and make use of; this was a very important issue for the DMs and stakeholders. Compared with the original AHP, REMBRANDT was chosen due to the theoretical improvements (Olson et al., 1995).

5. Developing a detailed analytical structure

At this point step 1 and 2 of von Winterfeldt and Edwards (1986, 2007) process have been dealt with. Therefore this section will concentrate on developing a detailed structure for the assessment of the case problem. This concerns the task of distributing subsidies from a public pool to bike project applications in order to make bikes a more attractive means of transportation for which the pair wise comparison technique REMBRANDT has been chosen.

In consultancy with the DMs the 133 projects were first divided into 3 main pools according to a characterisation of the project type. It was found convenient to express these as: innovation, safety or bike city projects. Second, a screening of the projects' characteristics shown it necessary to divide the 3 main pools into 9 sub-pools (3 for each main pool) describing each project type in a higher level of detail. As depicted in Figure 1 the sub-pools contained: knowledge/research projects, plan and concept projects and campaign projects (the innovation pool); school road projects, bike path projects and bike tourism projects (the safety pool); and bike city projects, commuting projects and bike parking projects (the bike city pool).

Consequently, the prioritisation task consisted of producing prioritised lists for each of the 9 sub-pools and hereafter combined pool lists for each of the 3 main pools. The final prioritised lists (one for each of the 3 main pools) thus contained the projects which were found worthy for subsidies from the bike pool. It should be noted, that it was by request from the DMs to divide the projects into 3 pre-specified main pools, and to derive a prioritised list for each of these instead of one overall list.

[Figure 1. Division of the projects into different types]

It was moreover necessary to determine what impacts (here denominated as criteria) that characterised the different project types in order to assess how well the projects contributed to promote the overall goal of the bike pool. In the previously mentioned workshop, with participation of key stakeholders and DMs, a long list of possible criteria had been created on the way to define the objectives in Table 2. In consultancy with the DMs relevant criteria from this list were now assigned to the sub-pools ensuring operationality. Each of the 9 sub-pools was henceforth based on a set of criteria defined to measure a change in impact relevant for the specific type of project. It was decided to limit the number of criteria to a maximum of the four most important for each sub-pool although more criteria were identified. This was done as a consequence of time constraints for the assessment process, and was moreover based on the assumption that more criteria would not contribute significantly to the assessment (von Winterfeldt and Fasolo, 2009). Table 4 provides an overview of the criteria used for comparisons in the sub-pools. For comparisons of projects across the sub-pools the objectives from Table 2 are used as general criteria.

[Table 4. List of criteria]

As a result of the characteristics of the case problem and the preferences of the DMs the overall assessment task was structured as depicted in Figure 2 where the overall goal is based on the 9 different project types in the sub-pools. Each of the 9 sub-pools is based on a set of criteria, where each criterion measures a change in impact relevant for the specific sub-pool, see Table 4. The criteria sets are depicted on the following level in Figure 2, and the bottom level shows the projects. The projects are divided into sub-sets for each sub-pool placing projects with similar investment costs in the same set in order to obviate the cost criterion at the initial stage. This exercise is done as a consequence of the large sizes of some of the sub-pools which made it practically inconvenient to use pair wise comparisons. By dividing the sub-pools into sub-sets considerably fewer pair wise comparisons have to be made at the initial stage. At this stage the costs are neutralised as a decision factor but the cost criterion becomes relevant again when projects from different sub-sets are compared. Pair wise comparisons of the projects are conducted for each sub-set under each of the criteria. The results of these pair wise comparisons are an assessment of the relative performance of each sub-set's projects in relation to the criteria applied. It should be noted that Figure 2 only shows the principal structure of the decision problem, in practice the 9 project sub-pools were of a very varying size containing between 4 and 36 projects.

[Figure 2. Principal structure of the decision problem]

In order to make the assessment of the projects as comprehensive as possible, the DMs met to systematically discuss and analyse the issues at a decision conference as described by Phillips (2007). The objective of such a decision conference is to deal constructively with the conflicting issues at hand so a common understanding of the issue can be achieved, see Mustajoki et al. (2007). In fact several decision conferences were held as the size of the decision problem made it impossible to handle everything in a two to three day meeting. Instead single day conferences focussing on specific sub-pools were held. This made it possible for the DMs to reflect over previous assessments in the days between the conferences and revise some judgments if this was felt appropriate. The conferences were held at the Technical University of Denmark's property in order for the DMs to get out of their normal surroundings as recommended by Phillips (2007) thereby making it easier for them to concentrate on the relevant issues. The conferences were controlled by an impartial facilitator that guided the DMs through the process of deriving input to the decision model – the CPP-DSS – which was operated by a decision analyst. Thus the CPP-DSS functioned to model the viewpoints of the participants and to appraise the projects in a manner that could be accounted for afterwards.

In this context it should be noted that all choices and assessments made during these decision conferences were documented in a so-called assessment protocol, which had the purpose of creating a documented rationale for later justifications. Efforts were made for the participants to reach consensus on each of the comparisons before moving on to the next. In the cases where it was not possible to agree upon the comparisons the different viewpoints were noted with a view to a later sensitivity analysis if felt needed by the participants.

The participants at the decision conference were by request from the political support base solely selected by the Danish Road Directorate. Thus the group consisted of government officers who all had specific areas of expertise in bike related issues and experience in the use of decision support tools. As a result of this it was possible to keep the analysis on a high level of problem understanding.

In overview the following steps A – F comprise the process of the CPP-DSS:

A. The applications for the projects are scrutinised and those applications that are not satisfying the standards defined are sorted out. The remaining projects are organised in the 9 sub-pools describing specific project types.

B. The projects are in each of the 9 sub-pools further divided into sub-sets consisting of 3 to 6 projects with similar project costs (in all 24 sub-sets are made).

C. By use of the REMBRANDT technique each sub-set is assessed using pair wise comparisons. Pair wise comparisons are made of all projects under all criteria in the sub-sets' criteria set. Next, pair wise comparisons are made of the criteria in order to determine the criteria weights. Following, project scores are derived and used to rank the projects in the sub-set. The result is 24 prioritised lists in total.

D. The highest ranked projects in each sub-set are gathered in a new set under the sub-pool. These so-called number ones's are compared pair wise under the same criteria as in step C, however, the cost criterion is now added as the projects have different costs. Consequently, project scores are again calculated and the projects are ranked within their sub-pool. The result is 9 prioritised lists.

E. It is now possible to create 3 prioritised lists using the so-called general criteria depicted in Table 2. From each pool-list the projects recommended for subsidy are identified using pair wise comparisons under the general criteria. These general criteria ensure that comparisons are made with regard to the overall goal of the bike pool. The projects are picked out one at a time as one of them reaches the highest rank on the list. When the budget frame is empty the process stops.

F. The 3 prioritised lists are presented for the political parties behind the agreement regarding the origin of the bike pool to consider.

When a project is picked out for subsidy in the previously mentioned step E, the project which was ranked second best in the original sub-set takes its place. Hence, pair wise comparisons have to be made again in order to determine whether this specific project is better than other projects, which were ranked higher in other sub-sets. This procedure ensures that all projects 'compete' at the same terms across the sub-sets and sub-pools, while at the same time it keeps the number of pair wise comparisons to a minimum. The procedure, however, does not necessarily ensure that all 9 sub-pools or projects with varying costs will be present in the final list. This depends on the specific assessments made during the process.

6. Discussion and findings

The results of the CPP-DSS were three lists – one for each main pool – consisting of those projects found appropriate for a subsidy from the bike pool. Figure 3 depicts the structure of the three lists determined by the analysis. Note that the letters denominates different project ID's, which are not shown here because of duty of confidentiality towards the Danish Road Directorate.

[Figure 3. Three prioritised lists of projects are the results of the CPP-DSS]

It can be noted that if all 133 projects were to be compared with each other in one large pool under all the criteria used one would have to conduct approximately 300,000 pair wise comparisons; a number which is evidently impossible to handle in practise. If, on the other hand, the projects were divided in 9 project type pools with 15 projects in each and assessed under 5 criteria (the four shown Table 4 plus the cost criterion) one would have to conduct approximately 5,000 pair wise comparisons; which is still a number practically impossible to handle. When using the CPP-DSS with the described analytic structure approximately 600 pair wise comparisons were conducted during the process. This is a large number when each comparison has to be well-argued, but it is manageable over a time period of a few weeks with frequent assessment meetings.

When conducting this type of appraisal the identification and definition of the criteria set is a crucial factor. The criteria need to be defined unambiguously and in a way so that no overlapping takes place. Moreover the group doing the assessments need to have a shared understanding of the criteria to minimise matters of dispute that can arise both during and after the assessment process.

An important issue that needs to be addressed when dealing with these many different types of projects (as has been the case for the CPP-analysis) is the placement of projects in sub-pools. The question addressed is whether a project which performs poorly within its sub-pool might perform better on criteria from another sub-pool. For this reason it is of utmost importance that the projects are placed in the proper sub-pool from the beginning of the analysis. If not, the projects are in risk of not being treated fairly and the funds from the bike pool not distributed in an optimal way. This of course sets some high requirements for the initial work on placing the projects in the right sub-pools.

Another important issue is the assignment of criteria weights as these are determined by individuals using the MCDA method. On the other hand, the performance (scores) of projects for each criterion is determined somehow more objectively, even if artificial scales are used for non-quantifiable criteria. However, the REMBRANDT technique contributes to overcoming this disadvantage by deriving weights in a quasi-independent manner, using pair wise comparisons that make it difficult to promote open biases towards specific criteria. Thus, REMBRANDT is a common method used for prioritisation when having a wide variety of choices. More specifically, with regard to the application of the DSS for the case study, the group that conducted the comparisons was composed of DMs involved in the project.

In addition to the above mentioned some specific findings can be related to the structure of the decision problem:

1. The structuring task should be conducted in close dialogue between the analysts, the DMs and the stakeholders. The dialogue should preferable be highly interactive and iterative leaving options for restructuring during the process.

2. Focus should be on solving the problem, not forcing a particular analytic structure onto the problem. This could even lead to the conclusion that the analytic structure originally considered for solving the problem (for the CPP case: CBA) is not the most appropriate for the problem.

3. A good structure emerges when social and technical facilitation skills are combined. The social skills enhance the likelihood that the DMs and stakeholders will participate in the process, provide important input, and appreciate the results. The technical skills assure that the analysis is logical, simple, manageable, and still relevant to the concerns of the DMs and stakeholders.

4. The CPP-DSS featuring the REMBRANDT technique has shown to be a useful tool when dealing with large complex problems that are in need of a clear structure in order to be solved. The method is moreover easily accessible for the DMs due to the simplicity of the pair wise comparisons.

5. It is seen as a major feature of the CPP-DSS that the various inputs needed from the DMs can help generate important discussions in the group. A future research task will be to explore the modelling and DM interaction further with the purpose of improving the learning and understanding among the DMs about the actual non-standard appraisal task.

6. Overall, inclusion of socio-economic elements in the assessment of transport projects is widely preferred. Future developments of the CPP-DSS should for this reason work towards inclusion of CBA as the necessary socio-economic foundation become available from research on this topic.

After the finalisation of the assessment task an evaluation meeting was held with the DMs where feedback on the entire process was given. Overall, the DMs were most satisfied with the process agreeing that a requisite model was achieved. The model was perceived to be very useful as it was simple enough to capture the essence of the decision problem, and not too complicated to understand for neither professionals nor non-professionals. The DMs expressed their satisfaction with the approach taken based on several small-scale decision conferences each focussing on specific project types. This enabled the participants to reflect on previous assessments and make corrections at the following decision conference if they felt a need for this. The use of pair wise comparisons was considered appropriate as the problem was decomposed into simple sets of judgments for the participants to consider. The documented rationale in form of the assessment protocol was in this respect a helpful tool both to remind the participants about previous assessments made, but also in informing the politicians and stakeholders about the choices made in the process. The DMs moreover stated that the analysis structure was requisite as no additional insights emerged along the process that led to significant additions or modifications of the structure.

7. Conclusions

This paper has described the structuring and appraising activities associated with a major decision analysis of projects to promote biking activities in Denmark – the CPP problem – and shows that decision analysis using MCDA can be a useful approach for structuring and appraising large and complex decision problems. Specifically, the paper examines the three-step structuring process for decision analysis proposed by von Winterfeldt and Edwards consisting of: framing the problem, selecting an appropriate structure, and developing this in detail before beginning the numerical modelling and analysis. The process has been applied to the CPP decision problem and emphasises the importance of creating a clear analytic structure before attempting to solve the decision problem. The use of decision analysis for the structuring of this specific case problem with a large number of options and multiple objectives was found to be very useful by the DMs. They felt that they had gained sufficient insight in the issues along the process and were for this reason well equipped for defending the results when afterwards facing both politicians and the public.

The MCDA approach presented in the paper has been based on the REMBRANDT technique for pair wise comparisons, which is found relevant as an assessment tool for the specific CPP case study where data and resources were limited for the appraisal. Due to the structure of the decision problem a procedure for limiting the number of pair wise comparisons needed to be made in the process has been set out and applied with a good result. In fact this procedure limits the number of necessary pair wise comparisons from approximately 300,000 in a complete analysis to approximately 600 when using the CPP-DSS. The paper has demonstrated that decision problems such as the treated CPP case do not present themselves in a structured form, complete with lists of alternative courses of action and decision making objectives (criteria), and ready for systematic analysis. Therefore problem structuring in terms of alternatives (projects) and criteria has been a main concern when illuminating the CPP methodology thereby being in accordance with the view that the treatment of components of a problem structure are central to the methodologies of MCDA.

The CPP case is indicative of a number of application areas where approaches similar to the CPP-DSS can be made use of but probably no single best problem structuring method for all decisions exists. The influence of contextual factors on the decision process is significant as is the initial frame taken by the DMs. These and other influences should be studied further as they impact the problem structuring process. The way the CPP-DSS reduces the number of pair wise comparisons can be useful due to its easy transferability to other problem applications generically like the treated.

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