Decision Simulation Technique (DST) as a scanning tool for exploring and explicating sustainability issues in transport decision making

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ABSTRACT

This paper places focus on explicit consideration of sustainability issues in transport decision making by presenting and using a developed "Decision Simulation Technique" (DST). This technique can be used by an analyst to 'scan' a transport planning problem with regard to what in DST terms is called a sustainability strategy. This scanning can serve the purpose of informing a group of decision makers before they actually have to deal with, for example, the choice among a number of alternatives that have all been formulated as being relevant. The main focus of the paper is to illustrate how the DST can indicate which one from the set of alternatives will in fact be the 'best' seen from the viewpoint of a sustainability strategy, before they are all scrutinised by the decision makers. The paper consists of three parts. The first part describes the various concepts and elements of the DST together with the principal steps that have to be followed when applying it on a concrete case. In the second part the potential of the DST is demonstrated by its use within an ongoing study. Thus the DST is applied on a new rail investment study on a section with four alternatives being part of a proposed new high speed rail line in Southern Sweden. The third part of the paper is concerned with a principal discussion of incorporation of sustainability in transport planning. It is argued that 'explicating'-techniques such as the DST compared to more traditional ways of doing this – here denominated implicit consideration of sustainability – can be useful for many different planning problems where the treated rail case is just one example. Finally, the paper offers some conclusions and a perspective on the future use and development of the DST.

Keywords: Sustainability, decision support, simulation of preferences, semi-soft methods, decision simulation technique (DST)

1. Introduction

This paper introduces a scanning tool named Decision Simulation Technique (DST), which can be used by planners and decision makers to simulate a decision process before the actual decision making process begins. The DST is intended to be a pre-decision making tool, conducted by a single analyst, providing information about which alternative that may be the most attractive one under an explicit sustainability strategy. The DST can indicate if some alternatives can be ruled out before the actual decision making process starts. The simulation process is based on information about identified and relevant evaluation criteria and the associated stakeholders' viewpoints are perceived as contenders to the explicit sustainability strategy developed in DST. Simulation of the decision process at the early stages of the planning process provides planners and decision makers with an opportunity to test alternatives against a specific sustainability viewpoint before the actual decision making process begins. Taking a specific sustainability strategy into consideration at an early stage allows the decision maker to conduct a pre-decision making screening of which alternatives that would be attractive under a sustainability viewpoint, the so-called sustainability strategy. This means that planners and decision makers can gain knowledge about which alternatives are of interest to bring forward for the final planning process, public hearings and decision making.

In this context the concept of sustainability is regarded as based on the following key values: long term perspective in the planning, consideration of assets which cannot be restored (e.g. landscape, and cultural heritage), and consideration of impacts on all stakeholders and criteria (Jeppesen & Pedersen, 2005). The application of sustainability viewpoints is sensitive towards the decision making environment. A sustainability strategy is often less convenient and more expensive in the short-term perspective, but more favourable in the long-term perspective. Test of alternatives against a mindset built on a sustainability approach is often left out as the main stakeholders with regard to these viewpoints are grassroots which may not be represented in the final decision making.

In the traditional transport planning sustainability viewpoints are often seen as an implicit part of the decision process. They are put forward in small incoherent parts by all or by a few dedicated participants (e.g. grassroots) who might also have other viewpoints to advocate for. The sustainability viewpoints can also be implicitly represented on paper by the Environmental Impact Assessment (EIA). Commonly the concept of sustainability may be mentioned frequently, but in an implicit structure it may not influence the decision making. The proposed DST can remedy this by being a kind of sustainability 'advocate' designed to represent the sustainability viewpoints. Such explication of sustainability viewpoints can be useful both at the early stages and towards the end of the decision process.

2. Decision Simulation Technique

The Decision Simulation Technique is designed to deal with complex transport planning situations. It can help to explicate the concept of sustainability and deal with the complexity related to implementation of the concept in transport planning. A systemic approach to decision making holds several advantages when the decision problem in question is said to be complex (Leleur, 2008). The DST is therefore based on a systemic approach to planning put into practice using a multi-methodology approach to decision making. The multi-methodology approach enables the use of more than one methodology and it furthermore allows a mix of methods from different paradigms and with different aims, see among others (Mingers and Gill, 1997). By using a multi-methodology approach to decision making it has been possible to select the methodologies and tools which are thought most helpful in a scanning process and as tools for making sustainability choices explicit. The DST consists of a combination of both soft and hard methods, which will each provide the simulation technique with problem solving and appraisal qualities. The soft methods are applied in a so-called semi-soft way. The basic principle of such application is that the methods are only used by the analyst performing the scanning. This means that during the application there is no direct stakeholder participation. The different stakeholders and their probable preferences are then simulated by the informed analyst. Application of soft methods in a semi-soft way has been proven a possible approach by Jeppesen et al. (2008) and allows planners and decision makers to gain important information from participatory methods with a minimum use of time and resources. Such applications of the traditional soft methods are chosen, as the DST is supposed to be used as an initial scanning providing planners and decision makers with information about the alternatives that could be of interest for the subsequent appraisal and decision making process. In the DST no final decision is to be made, but initial information is gained for the 'real' planning and decision making process.

The Decision Simulation Technique consists of three interrelated modules, see Figure 1. The three DST modules represent the Decision Problem (DP), a Stakeholder Analysis (SA) and a Preference Analysis (PA), respectively. The modules considering the decision problem and the stakeholder analysis are solely based on soft methods. The third module regarding the preference analysis draws on both soft and hard methods. The general steps within the three modules of the DST are described further in (Jeppesen, 2009).

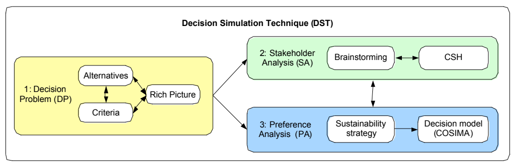

Figure 1 Overview of the methodologies and relations forming the Decision Simulation Technique (DST)

2.1 Module 1 – Decision Problem

The first module considers the Decision Problem (DP). It regards the properties of the decision problem such as the alternatives and the criteria under which they should be evaluated. This information is sometimes given, but can be determined as a part of the DST using a 'series of brainstorms' and all available material regarding the decision problem. The first module concerns the understanding of the decision problem using Rich Pictures (RP). RPs were developed as a tool for the 'finding out about the problem situation' phase in Soft Systems Methodology (SSM). The concept of SSM will not be explained further as only the RP tool will be used. For information on SSM, (Checkland, 1993, 1999) and (Checkland and Poulter, 2006) can be consulted.

RPs can be used to interpret, describe and structure a problem situation, not in sentences alone, but by simple drawings which can be accompanied by essential words and sentences. This technique allows for very difficult situations to be summarised and communicated by a single piece of paper. The technique is a very useful tool for describing and communicating relations between the implicated stakeholders and their different views. A RP can help to provide in-depth understanding of different aspects of a problem situation regarding structure, process and climate. An RP is a snapshot of the problem situation at the given time and thus not a static component. RP can and must be conducted throughout the whole intervention due to the dynamic complexity of the problem situation (Checkland and Poulter, 2006) and (Leleur, 2008).

RPs can be useful in two ways for the DST. If the alternatives and the criteria are given in advance, RPs can be used to communicate the different properties of the problem situation. Pros and cons of the alternatives can be brought forward, whereby some stakeholders might be framed for further analysis by module 2. If the alternatives and criteria are not given, an RP can be used as inspiration for the brainstorming process used to define them.

Alternatives, criteria and RPs are interconnected by double-headed arrows indicating shifting information, influences and relations due to all three elements. Module 1 relates to both modules 2 and 3 as it serves as information feeder, see Figure 1.

2.2 Module 2 – Stakeholder Analyses

The second module concerns the Stakeholder Analysis (SA) and depends on brainstorming and Critical Systems Heuristics (CSH) which, indicated by the double-headed arrow, are used to inform each other, see Figure 1. Brainstorming for stakeholders is based on the understanding of the problem situation gained in module 1 and developed from the accessible information regarding the decision problem. CSH, initially developed to assist planners and citizens with social planning, is in the DST used to develop the brainstorming both in terms of understanding the present and the desired situation. CSH consists of 12 questions which can be asked both in 'is' and in an 'ought to' mode, helping to understand which actors are involved or not, and what their roles, knowledge and relation to the decision making are. CSH is developed upon the theory of critical reflection in order to understand the situation, improve planning and emancipate affected stakeholders. CSH will not be further described here but (Ulrich, 1983) and (Ulrich, 2005) can be consulted for further information.

Using CSH as part of the SA analysis in the DST is useful as it can provide the scanning with insides regarding possible stakeholders, their roles and viewpoints. The most important benefit from CSH in relation to DST is the opportunity to get to know if there is a difference in who are actually considered as stakeholders and who ought to be. The information from the stakeholder analysis is used to develop and shape the sustainability strategy which is applied in the third module.

2.3 Module 3 – Preference Analysis

The third module concerns a preference analysis (PA) performed to explore the sustainability strategy, which is carried out, among other things, by using an appropriate decision model. The third module is developed based on the information from module 1 and an interaction with module 2, see Figure 1. Before the COSIMA decision model can be applied the sustainability strategy has to be defined. Definition of the sustainability strategy is of vital importance for the DST's ability to explicate the concept of sustainability in the scanning process.

The sustainability strategy is developed for each individual decision problem and builds upon the stakeholder viewpoints gained from the SA in module 2. Development of the sustainability strategy is based on the key values and designed by the analyst performing the DST.

The PA is based on the COSIMA decision model. It combines the information obtained in modules 1 and 2 with the sustainability strategy set out in module 3. The COSIMA decision model consists of a cost benefit analysis (CBA) and multi-criteria analysis (MCA). CBA and MCA are applied in a joint approach, enabling them to be combined into a Total Rate of Return (TRR), which is the model output indicating the attractiveness of an alternative. The technical note at the end of this paper gives the details on the technical aspects of the COSIMA decision model, but the main principles can be outlined by using the following case.

3. The case of Ostlänken from Bäckeby to Norrköping

The planning of a new rail connection in Sweden is used to present the DST. The part section running from Norrköping to Bäckeby is part of a larger railway project named

Östlänken. Ostlänken is a rail connection between Linköping and Järna in Sweden and is one part section of a large rail project aiming at strategic goals, shorter travel times, environmental and travel safety achievements. The Ostlänken rail line is part of the Swedish high speed rail strategy and related to the European TEN-T transport network. The whole Ostlänken rail connection consists of some part sections with several alternative corridor alignments and is presently under evaluation (KHR Rundquist & Andersson Jönsson, 2007) and (Banverket, 2008). The case concerns the appraisal of four alternative corridor alignments and a variety of both monetary and non-monetary criteria are considered.

This case study deals with the evaluation of the part section of Ostlänken from Norrköping to Bäckeby. This part section is part of a research project concerned with development of decision support systems suited for public transport projects (Vinnova, 2009) and has four alternative alignment proposals: Red, Blue-long, Blue-short, and Green, (Banverket, 2008). All the alternatives are describing a corridor and not a specific alignment. The corridors are named with colours, and short/long relates to the same corridor alternative but with two different tunnel solutions. Some characteristics of the alignments can be described as follows:

Red: This is the base alternative using the existing rail. It dominates the townscape in several areas and has inconsistency with the natural and cultural environment.

Blue, long tunnel: The alignment is to a large content similar to the Red alternative, besides from the passage of the existing townscape, as a significantly longer tunnel is used, which helps to minimise the passage problems.

Blue, short tunnel: The alignment is to a large content similar to the Red alternative, besides from the passage of the existing townscape, as a longer tunnel is used, which helps to minimise the passage problems.

Green: This alignment differs a lot from the existing line passing the existing townscape without problems. This corridor alternative proposes a soft curve around the existing townscape, but passes through areas of untouched nature, where several valleys will be split.

The four alternatives have been evaluated by a conventional CBA (Vinnova, 2009) and by a verbal MCA performed by Banverket, (Banverket, 2008). The criteria used by Banverket are also used for this case study appraisal. The MCA-criteria are: city and scenery impression, cultural environment, natural environment, recreation and outdoor life, health, natural resources, risk and safety, and building time. The defined alternatives and criteria as well as the conducted CBA and the verbal MCA will be used as input for the DST.

Application of DST to the Ostlänken case demonstrates how the DST can provide early information about how an approach to decision making based on an explicit sustainability viewpoint can influence the appraisal outcome. In the following the DST process is described and afterwards the DST results are compared to the outcome of a Decision Conference (DC) representing the 'real' process.

4. Application of DST to the Ostlänken case

With the alternatives and the criteria set from the start, the first step in the DST is a further understanding of the problem situation. Indications of inconsistency between the goals and the objectives of the stakeholder groups are revealed by a RP conducted as part of the initial work on the case. A number of relevant criteria are presented in the EIA carried out for this part section of Ostlänken. A sustainability strategy is defined by making a ranking of these criteria, see Table 1. The sustainability strategy depends on the defined values, see section 1, and the criteria concerning areas which cannot be completely restored if they are demolished are therefore the highest ranking.

Table 1 Overview of the criteria and how they are prioritised in relation to the sustainability strategy

Criteria	Ranking
Natural environment	1
Cultural environment	2
Recreation and outdoor life	3
Natural Resources	4
City and scenery impression	5
Health	6
Risk and safety	7
Building time	8

The next important step of the DST consists in scoring the alternatives under each criterion. Technically this is done by making use of pairwise comparison of the alternatives. In this case the comparison was provided by the EIA report (Banverket, 2008). Based on the pairwise comparisons, two criteria (risk and safety and building time) can be ruled out as all alternatives performed equally under these criteria. The process continues with the resisting criteria (ranking 1-6) shown in Table 1. The described steps 1 and 2 makes it possible to perform the calculations of the MCA part of COSIMA. The third step concerns a weighting together of the available CBA information with the MCA information obtained. A principal linking of the CBA and MCA is shown in Figure 2.

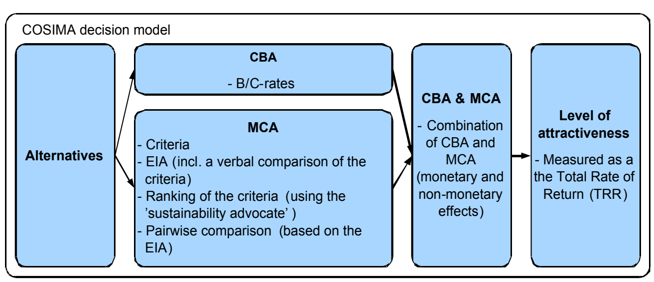

Figure 2 Overview of the COSIMA decision model

The DST indicates that the red corridor alternative will be the most preferable one until a MCA-% of approximately 20; at this point the red and the two blue corridor alternatives are approximately equal, and after this point, i.e. with a MCA-% above approximately 20, the blue corridor alternative with the long tunnel is the most preferable alternative. The results of the scanning performed with the DST are illustrated by the graphs in Figure 3. From this figure it can be seen that if it is chosen to access the alternatives based on a combination of the CBA and the MCA, by the TRR, the MCA-% must be above 20 to provide a change from the CBA result alone.

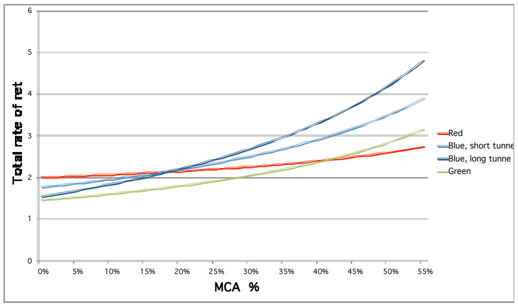

Figure 3 DST-graphs showing the TRR equivalent to all MCA values for each of the alternatives

In the sustainability strategy the non-monetary criteria of the MCA are considered as much more important than the monetary criteria of the CBA. The DST scanning shows that if the alternatives are assessed under a sustainability viewpoint as described and if a MCA-% above 20 is chosen, the blue corridor alternatives are by far the most interesting ones. If the MCA-% for the real decision making process is chosen to be above 20, the red corridor alternative can be ruled out at an early stage and so can the green corridor alternative as it never becomes the most preferable.

5. Application of a Decision Conference (DC) to the Ostlänken case

A Decision Conference (DC) based on the same decision model as applied in the DST has been conducted upon the same decision problem as in the DST. In this context it represents the ‘real’ decision making. The obtained DC results are used as a comparison reference to the DST results. The latter results are based on an explicit sustainability strategy, whereas the results obtained from the decision conference are based on the preferences of the participating stakeholders.

A DC is a tool which can be used to bring together stakeholders with the purpose of having a structured debate about a given problem situation. According to Philips (2006) such conferences have helped groups to achieve a shared understanding of issues without requiring the group to achieve consensus about all issues. The most important thing for a successful decision conference is actively participating stakeholders. Other requirements are: attendance by key players, impartial facilitation, on-the-spot modelling with continuous display of the developing model, and interactive and iterative group process (Philips, 2006, p. 5).

The decision conference was part of the Vinnova research project (Vinnova, 2009) and organised as a half day workshop, involving stakeholders who could all be characterised as experts on their field. The process was structured as a debate about the criteria defined in the EIA. In this case the predefined criteria from the EIA report were used. The conference was guided by a facilitator supported by two model technicians using the COSIMA decision model to perform on-the-spot modelling of the obtained results. Three expert participants attended the decision conference which was held in Norrköping in Sweden at the 27th of January 2009 from 1 pm to 5 pm. The programme, the facilitator and the model technicians were presented to the participants during the introduction to the intervention. The first task was to prioritise the criteria through a group decision, where the participants were asked to achieve consensus about the importance ranking of the criteria. Eventually the structured debate summarised the prioritising as shown in Table 2. This input was applied to the COSIMA decision model.

Table 2 The DC participants joint prioritising of the criteria from the EIA report

Criteria	DC Ranking
Cultural environment	1
Natural environment	2
City and scenery impression	3
Recreation and outdoor life	4
Natural Resources	5
Health	6
Risk and safety	7
Building time	8

Afterwards the participants were asked to go through a complete pairwise comparison of the corridor alternatives under the criteria one by one. Information about which alternative was the better (and how much better) than the other in the comparison or if they performed evenly under the criterion was filled into the decision model. When all the pairwise comparisons were completed the participants were introduced to the CBA–results (which they had been provided on before hand) and informed about the theoretical understanding of the concept MCA-%, which they were to decide afterwards. A group discussion very soon led to a consensus about working with a MCA-% of 50. In fact this was the initial suggestion from all three participants. The results of the group process were then computed in the decision model, see the technical endnote.

If the complete set of results is scrutinised it can be seen that the red corridor alternative is the best until an MCA-% of about 10, and that the blue corridor alternative with the short tunnel will be the most attractive alternative when the MCA-% is chosen to be above 10. Figure 4 illustrates the development of the TRR for all alternatives with regard to MCA-%. This clearly illustrates how the red and the green corridor alternatives are not of interest with a MCA-% above 10. Figure 4 furthermore shows that even though the blue corridor alternative with a long tunnel never becomes the most preferable, it follows a curve with a shape approximately identical to the one of the blue corridor alternative with a short tunnel.

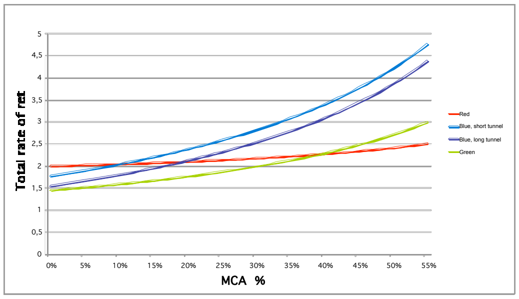

Figure 4 DC-graphs showing the TRR for all MCA-% values for all four corridor alternatives (Vinnova, 2009)

6. Comparison of the two applications of decision support

In the DST the criteria in the sustainability strategy were prioritised according to the identified key values described in section 1. Afterwards the scoring of the alternatives under each criterion showed that two criteria (risk and safety and building time) could be ruled out as all alternatives performed equally with respect to these criteria. They are therefore shown as blanks in Table 3. The same criteria set was used in the DC, where the participants, however, prioritised them differently from the sustainability strategy criteria ranking in the DST. The DST and the DC criteria rankings are shown in Table 3. Note that the criterion 'health' was the only one that obtained the same prioritising in the two approaches.

Table 3 Criteria ranking in respectively the DST and the DC

Criteria	DST, sustainability strategy ranking	DC, participants ranking
Natural environment	1	2
Cultural environment	2	1
Recreation and outdoor life	3	4
Natural Resources	4	5
City and scenery impression	5	3
Health	6	6
Risk and safety		7
Building time		8

The DST scanning was completed with a sustainability strategy choosing no specific MCA-%. It was only stated that the MCA was much more important than the CBA, which points towards a MCA-% higher than 50. The participants of the DC chose a MCA-% of 50.

A large similarity between the two sets of results (see the graphs in Figure 3 and Figure 4) is the information that the green corridor alternative never becomes interesting and can be ruled out at an early stage. Another similarity is that the red corridor alternative only becomes interesting with an MCA-% approximately below 20 (DST) and 10 (DC), respectively. Other information which can be drawn from the results is that the change of the most interesting corridor alternative in both approaches happens at a low MCA-%, and the corridor alternative which becomes the most interesting at this point stays the most preferable.

The DST points out the two blue corridor alternatives as being of interest for further investigation, and the DC appoints the blue alternative with the short tunnel as the experts' decision and the blue corridor alternative with the long tunnel as the second most interesting. In both cases the blue corridor alternatives are thereby the most interesting and the ones to investigate further and eventually choose between.

As described, the DST sustainability strategy and the DC 'real' results do not differ much. In this respect, it can be noted that the DST could also have been used with another strategy implementation than sustainability. If, for example, a strategy built upon values concerned with economic considerations is adapted another result will be obtained. With an economic ranking as shown in Table 4 the results in Table 5 appear. These may be interpreted in the following way: with the sustainability strategy an MCA% of 50 may be likely, whereas an MCA-% of 10 may be more likely with an economic strategy. This serves to illustrate that the DST applied on the economic strategy instead of the sustainability strategy will produce another result, with the red alternative to be preferred to the blue long.

Table 4 Overview of the criteria ranking in the sustainability and the economic strategies applied in the DST, respectively.

Criteria ranking	Sustainability strategy	Economic strategy
1	Natural environment	Natural resources
2	Cultural environment	Health
3	Recreation and outdoor life	Natural environment
4	Natural resources	Cultural environment
5	City and scenery impression	City and scenery impression
6	Health	Recreation and outdoor life

Table 5 Results of the sustainability and the economic strategies, respectively, with regard to different MCA-%. The bold result indicates the recommendation of the DST based on each strategy

MCA-%	Sustainability strategy	Economic strategy
10%	Red	**Red**
30%	Blue-long	Blue short
50%	**Blue long**	Blue short/long

7. Conclusion and perspective

A scanning based on the DST is based on the use of semi-soft and hard methods and thereby not on direct stakeholder information. Application to the Ostlänken case has shown that this approach is useful as a scanning tool indicating how real stakeholders may perform and decide. When moving from the pre-decision making use of semi-soft-methods to the actual planning involving real stakeholders, a DC based on soft and hard methods can be used to ensure a structured debate based on group techniques, IT and technology.

The three modules of the DST provide an approach to operationalise the concept of sustainability by working out a sustainability strategy. The strategy is used to explicate the sustainability viewpoints. The strategy necessarily depends on the criteria and alternatives defined in module one. These are therefore of great importance for the results as they determine how the concept of sustainability is concretely defined in the process. Seeing it as an 'advocate' ensuring that sustainability issues are incorporated in the planning and decision making process therefore necessitates that each of the DST steps must be validated as concerns the information used and processed. Thus the 'advocate' is only as strong as the criteria relevant to express and evaluate the viewpoints of sustainability.

The pre-decision making assessment of the Ostlänken part section from Norrköping to Bäckeby under a sustainability viewpoint has shown that the DST is capable of providing information relevant for the 'real' planning and decision making process. The DST scanning indicated that when assessed under the sustainability strategy the two blue corridor alternatives would be of interest and that the red and green corridor alternatives could be ruled out at an early stage.

Comparison of the outcome of the two approaches to the Ostlänken case shows that the pre-planning scanning with the DST sustainability strategy and the real planning with stakeholders in the DC had several similarities. They both identified the two blue corridor alternatives as the most preferable ones, and they both indicated that the green corridor alternative never becomes of interest and that with a MCA-% above 20 the red corridor alternative can be ruled out as well. The similarity of DST sustainability strategy and DC 'real' results in the case study may be interpreted to indicate that the participants of the DTC represented the sustainability viewpoints well. In cases where this is not so, the DST will be useful as a tool that makes it possible to indicate the best sustainable alternative to be set against the alternative that may be preferred and set on the agenda by a 'strong' stakeholder.

The DST provided an enlightening pre-planning input which could have ruled out two alternatives before the actual planning process started. This indicated that the DST can serve as a scanning tool for planners and decision makers to simulate explicit sustainability viewpoints at an early stage and thereby help to simplify the planning process.

In this paper it is demonstrated how the DST can explicate the concept of sustainability for transport planning through a sustainability 'advocate' who represents the sustainability viewpoints as a sustainability strategy throughout a decision process. This enables the concept of sustainability to shift from being an implicit part of planning and decision making to being an explicit part. The impact of the sustainability viewpoints are thereby enhanced in a transparent way, which can help planners and decision makers while they are working with complex transport planning problems and decision making. The DST furthermore makes it possible to test other strategies relevant to the decision problem, e.g. an economic strategy. This can be especially relevant if the CSH reveals a stakeholder group with great influence on the decision or a stakeholder group which is in complete opposition to the applied strategy, e.g. a stakeholder group in strong opposition to the sustainability viewpoint. The possibilities and use of the DST in planning situations can be developed and refined in such a way that more viewpoints than the ones of the explicit sustainability advocate can be present in the planning process.

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The Vinnova project provided an excellent chance to test the developed semi-soft Decision Simulation Technique (DST) and compare the pre-decision making scanning results with data obtained from a decision conference. The Vinnova project has thereby been of virtual importance for testing DST. Furthermore, my colleagues in the Decision Modelling Group at DTU Transport have been most helpful regarding the use of the decision model and our joint performance of the decision conference in Norrköping on the 27th of January 2009.

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Decision Simulation Technique (DST)

Technical Note: The COSIMA decision model

The COSIMA decision model allows decision makers to conduct a composite analysis of a given decision problem. The main methods are the conventional cost-benefit analysis (CBA) which deals with the monetary impacts and the multi-criteria analysis (MCA) which is used to determine the effect of the non-monetary impacts. The decision model permits a combination of input from a CBA and a MCA into a Total Rate of Return (TRR). The TRR is calculated by the equation below, see (Salling et al., 2006). The equation describes how the sum of the non-monetary benefits is multiplied with a calibration factor and added to the sum of the monetary benefits for a given alternative. These are then divided by the sum of the costs regarding the alternative.

$$TRR(A_k) = \frac{1}{C_k} \cdot \left(\sum_{i=1}^{I} V_{CBA}(X_{ik}) + \alpha \cdot \left[\sum_{j=1}^{J} w(j) \cdot V_{MCA}(X_{jk}) \right] \right)$$

∞	The calibration factor that expresses the model set-up's trade off between the CBA and the MCA
A_k	Alternative k
C_k	The total costs of alternative k
$TRR(A_k)$	Total rate of return for alternative k
$V_{CBA}(X_{ik})$	The value in monetary units for the CBA effect *i* for alternative *k* for altogether *I* CBA impacts
$V_{MCA}(X_{jk})$	The value-function score for MCA criterion *j* for alternative *k* for altogether *J* MCA criteria
$w(j)$	The weight that expresses the importance of criterion *j*
X_{ik}	CBA effect *i* with regard to alternative *k*
X_{jk}	Criterion *j* with regard to alternative *k*

The CBA elements, e.g. the monetary cost, $C_{k,}$ and the benefits, $\sum_{i=1}^{I} V_{CBA}(X_{ik})$, are calculated as in a conventional CBA and will not be further described here, see among others (Salling et al., 2006) for a full detail description. This is referred to as the CBA part of the COSIMA analysis.

The MCA part, $\alpha \cdot \left[\sum_{j=1}^{J} w(j) \cdot V_{MCA}(X_{jk}) \right]$, is based on applying additive value functions, used to assess the alternatives with regard to the criteria. There are several techniques which can be applied to conduct the MCA. The techniques used in the decision model for the present case is briefly outlined step by step in the following paragraphs.

First step is to prioritise the criteria according to their importance. The prioritising is based on the SMARTER method, see (Goodwin & Wright, 1998) applied with Rank Order

Distribution (ROD) weights, see (Roberts & Goodwin, 2002). These techniques only require the decision makers to rank the MCA criteria in order of importance, without a specification of the weightings, as these are determined directly by the ROD technique. The step determines the importance weight of each criterion, the w(j).

Following is 'direct rating using pairwise comparisons' used to assess all alternatives towards each other under all criteria, see (Belton & Stewart, 2002). The pairwise comparisons are based on the REMBRANDT technique, see (Olson et al., 1995). The comparisons are used to produce value-function (VF) scores. These scores are then multiplied by the ROD weights.

Finally, the MCA part is multiplied by a calibration factor, □, which indicates the trade-off level between the CBA and MCA. This trade-off basically describes the level of importance subscribed to the MCA when it is added to the CBA. The decision model is used to transform the monetary CBA impacts and the non-monetary MCA impacts into the same 'language'. This is done by assigning fictitious monetary values to the non-monetary elements, using the calibration factor □ and the weight indicating the importance of criterion j, w(j). This language is not to be compared with the conventional economic language, and the TRR is to be seen simply as an indicator of the individual attractiveness of the compared alternatives.

The CBA results are at all times kept 'intact', as the TRR are merely increased in the calculation by the chosen level of the MCA, expressed by a relative percentage, indicated by the MCA-%. The level of the MCA-% can vary, dependent on the decision makers' approach to the decision problem and how they rate the importance of the MCA. If the CBA and the MCA are equally important the MCA-% will be 50. If only the CBA is counted and the MCA is considered not to be of importance at all the MCA-% will be 0. If the MCA is much more important than the CBA, the level of the MCA-% can approach 100.

The TRR determined for each of the alternatives can be used as an indicator of the alternatives' individual attractiveness and illustrated as a function of the MCA-%. This function can be used to illustrate where the MCA part provides a change with regard to which alternative is the most attractive. If the decision model is applied with a number of stakeholders it can be used to illustrate their different preferences and their approach to decision making.

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