THE SUSTAIN APPRAISAL FRAMEWORK: FLEXIBLE DECISION SUPPORT FOR NATIONAL SUSTAINABLE TRANSPORT PLANNING

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ABSTRACT

Sustainable transport planning necessitates a rethinking of traditional decision making based on cost-benefit analysis (CBA) used for a systematic quantification and comparison of the various benefits and costs generated by a transportation project or policy. Generally, CBA has been found less useful for the handling and assessment of multiple, often conflicting objectives or criteria like environmental or social issues intrinsically difficult to quantify. Therefore, it is necessary to broaden the decision making process beyond merely economic factors. A new research project in Denmark on Sustainable National Transport Planning (SUSTAIN) seeks, among other things, to develop a flexible decision support model to include and assess sustainability indicators in a socio-economic framework, the SUSTAIN Appraisal Framework (SAF).

The SAF comprises two parts, namely a process part consisting of decision conferences and an analytical tools part consisting of an Excel-based software model. The latter employs the use of CBA, multi-criteria decision analysis and risk analysis techniques enabling the assessment of non-quantifiable impacts within a decision support context. The concept of a decision conference is introduced as relevant for dealing with various strategic elements not included in the CBA. The paper presents the SUSTAIN findings from an appraisal study of the Trans-Baltica railway corridor. In the study four alternatives are appraised with an explicit consideration of each alternative's sustainability performance.

SUSTAIN is rooted in cross-disciplinary sustainability research that recognises that a transition towards sustainability must involve normative, analytical and strategic issues to be successful. The paper concludes that the SAF can contribute to the analytical dimension. SAF allows for the appraisal of indicator sets in a socio-economic appraisal setting for national sustainable transport planning which enhances both the concept and principles of sustainable development while at the same time it provides flexible decision-support for policy-makers. Finally a research perspective is outlined.

Keywords: Analytical tool, strategic appraisal, robustness, multi-criteria, sustainability

INTRODUCTION

Today's decision-makers (DMs) are expected to be socio-economically responsible when taking decisions – but also socially responsible with regard to sustainability, equity, and so on. In most real-world policy situations, there are many alternatives, many uncertainties, many stakeholders and many consequences of interest (Walker, 2000). Together with the fact that there is usually no single decision-maker, this means that getting agreement will typically be based on a number of factors – or decision criteria – which make multi-criteria decision analysis (MCDA) become a useful tool for the decision-makers. MCDA should not be seen as a prescriptive answer (often there is no optimal solution), but as a transparent and informative framework when including analytical modules embedded in a decision process. The purpose of such a framework is to enable people to uncover their intuitive decision procedures by being informed following a structured rational analytic process (Ananda and Herath, 2009). MCDA helps decision-makers choose one course of action from among many, often complex possibilities. Important in this respect is that MCDA is a decision aid that in no way aims at replacing the judgement of the decision-makers.

Sustainability and sustainable development

Current national transport planning and decision making is challenged by incorporating a sustainable development of the transport system as expressed by many governments in recent years. In Denmark, the Government and Parliament have reconfirmed this ambition in an infrastructure plan on "Sustainable transport" and a political agreement on a "Green Transport Policy", which was decided in 2009. Thus national transport planning has to adopt principles of sustainability making it highly relevant to outline the contents of national sustainable transport planning (NSTP). A new research project in Denmark on Sustainable National Transport Planning (SUSTAIN) seeks, among other things, to develop a flexible decision-support tool to assess sustainability indicators in a socio-economic framework, referred to as the SUSTAIN Appraisal Framework (SAF).

In SUSTAIN (2012-2016) NSTP has been defined as: *frameworks, procedures and activities that seek to:*
"…integrate sustainability in the design and implementation of comprehensive national transport polices and plans" (Hedegaard et al., 2013).

SUSTAIN has adopted a cross-disciplinary research approach that recognises that transition towards sustainability must involve normative, analytical and strategic issues (dimensions) to be interlinked and active to make NSTP successful. This paper mainly concerns the analytical dimension with a focus on the SAF. Specifically, the framework allows socio-economic and sustainable appraisal to be carried out based on indicator sets derived from criteria sets that comprise national transport objectives which can be categorised as economic, environmental or social. By using SAF decision-makers are actively involved in the decision-making process, and therefore they can become fully aware of the sustainable development conflicts to be managed and the trade-offs to be made (De Brucker et al., 2013).

A schematic and indicative view of the challenge of NSTP can be presented by two planning approaches, which illustrate some principal differences between what can be termed conventional transport planning to be referred to as a business-as-usual (BAU) approach and a sustainable development (SD) type of planning approach. The schema below in Table 1 is based on Banister (2008) and Marshall (2001).

Table 1 Two transport planning approaches: Business-as-usual (BAU) and Sustainable Development (SD)

Conventional approach – Transport planning and engineering (BAU)	**An alternative approach - Sustainable mobility (SD)**
Physical dimensions	Social dimensions
Mobility	Accessibility
Traffic focus, particularly on the car	People focus, either in (or on) a vehicle or on foot
Large in scale	Local in scale
Street as a road	Street as a space
Motorised transport	All modes of transport often in hierarchy with pedestrian and cyclist at the top and car users at the bottom
Forecasting traffic	Visioning on cities
Modelling approaches	Scenario development and modelling
Economic evaluation	Multi-criteria analysis to take account of environmental and social concerns
Travel as a derived demand	Travel as a valued activity as well as a derived demand
Demand based	Management based
Speeding up traffic	Slowing movement down
Travel time minimisation	Reasonable travel times and travel time reliability
Segregation of people and traffic	Integration of people and traffic

The transport planning process consists of many activities that are interconnected, which is illustrated in Figure 1 below stemming from (Khisty et al., 2012, p. 538). As can be seen appraisal can be carried out with respect to several types of study issues; as concerns the SAF this is illustrated later on with a case example based on appraising four alternatives for a railway corridor thus mainly relating to project evaluation in the figure. However, the appraisal framework will be developed as a generic type of evaluation tool so it can handle also policies and in principle all the different types of appraisal issues referred to in Figure 1.

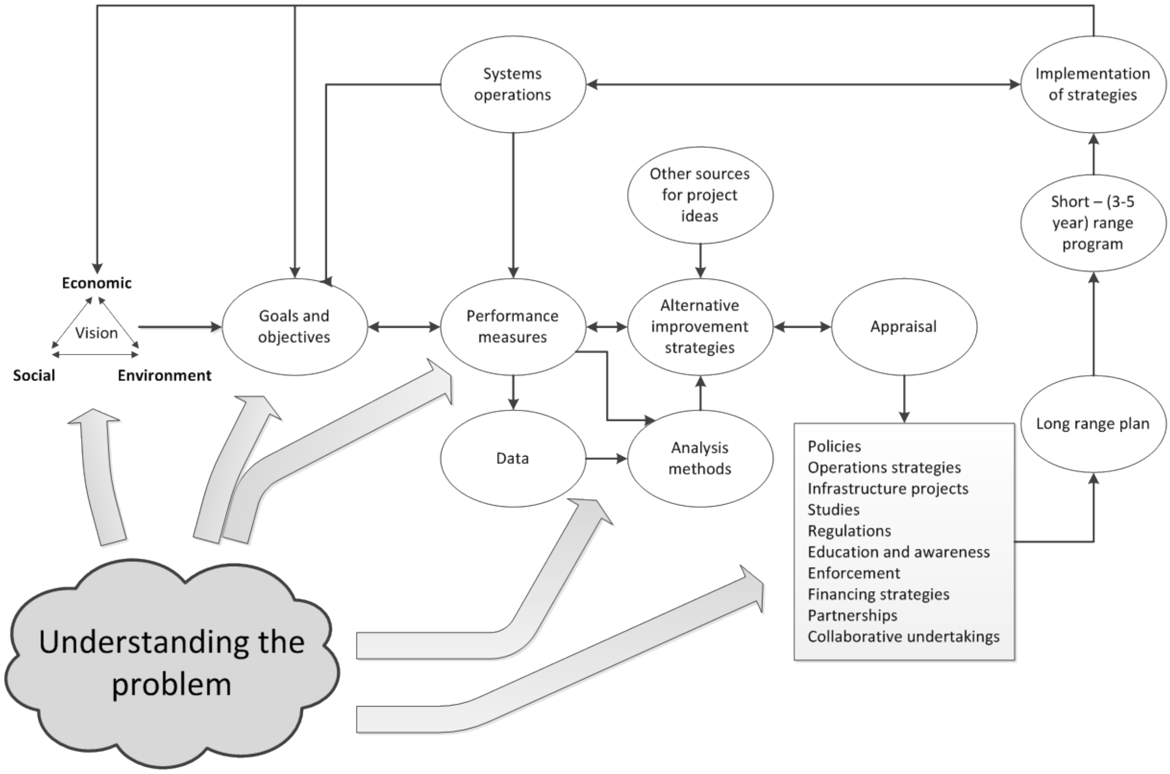

Figure 1 Appraisal as part of the overall transport planning process (Adapted from Khisty et al., 2012, p. 538)

THE SUSTAIN APPRAISAL FRAMEWORK (SAF)

Sustainability assessment and overall approach

Several efforts have been made to translate the various existing definitions of sustainability into applicable criteria or indicators for assessing the sustainability of projects or policies. The Swiss Government's Sustainable Development Strategy (Swiss Federal Council, 2008) and The Transportation Research Board guidebook for sustainability performance measurement (Zietsman et al., 2011) are good examples on sustainability indicators. However, there is often difficulty in identifying suitable data sources for appropriate indicators. In the first version of the SUSTAIN Appraisal Framework (SAF) a Long List of criteria has been set up to make sustainability assessment possible. In the on-going work of SUSTAIN this Long List of criteria will be tested and refined. Figure 2 presents the current status.

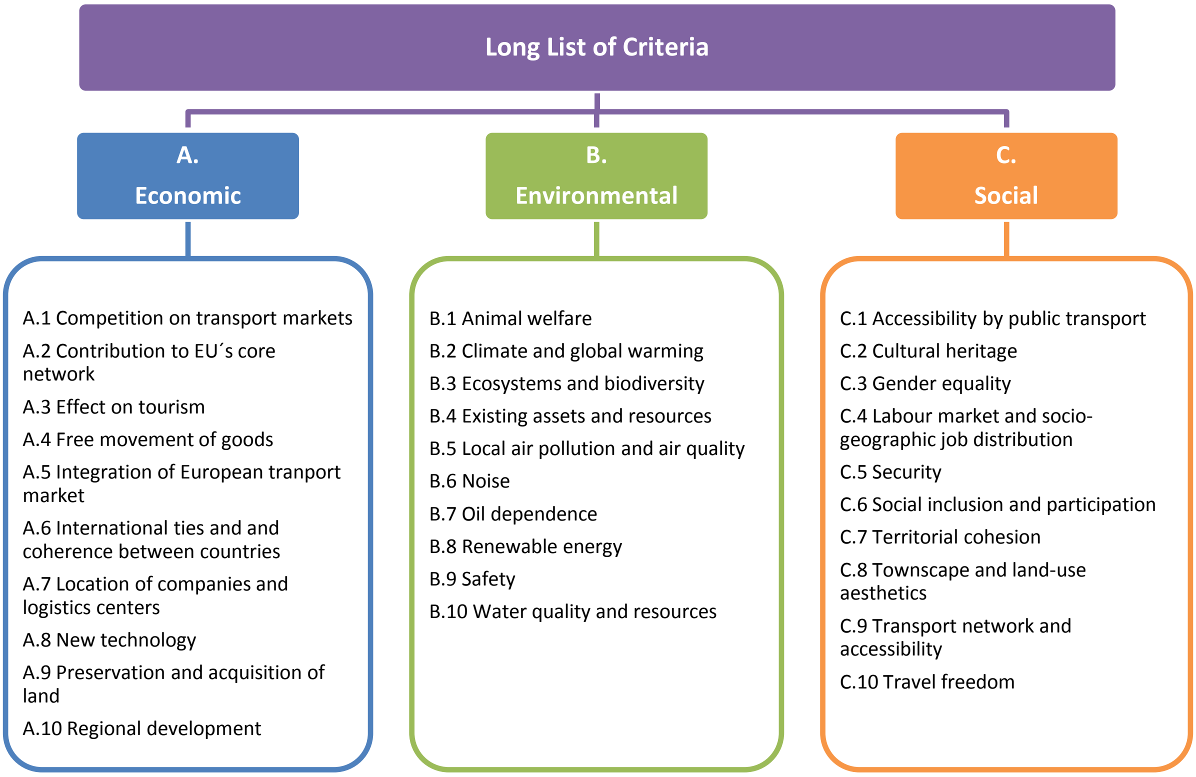

Figure 2 The Long List of criteria made use of in the first version of the SUSTAIN Appraisal Framework elaborated with respect to the three traditional pillars of sustainability: economic, environmental and social pillar (within each category listed in alphabetical order)

The purpose of the list is to support the work by providing a broad range of national transport planning objectives found relevant for making sustainability operational in appraisal of large transport infrastructure projects in the context of national sustainable transport planning (NSTP). It is assumed that benefit-cost ratios (BCRs) are calculated. Based on elements in the CBA it should be observed that double counting is avoided. To exemplify: if noise is part of the BCR calculation the noise criterion should be excluded from the Long List.

The Long List of criteria has been produced based on including criteria commonly made use of in the Scandinavian and several European countries. Furthermore, a number of criteria are based on the EU Roadmap (European Commission, 2009), for which reason their formulation and description can be seen to follow this text.

The ‘vision’ for a new transport infrastructure project is illuminated by selecting a Short List of criteria based on the Long List. Typically, this vision is assisted by scenario thinking. Some scenarios to exemplify can be: Business-as-usual (BAU), Sustainable development (SD) and Crisis and stagnation (CS). For each vision/scenario/development strategy typically the seven most relevant criteria are selected. These criteria are then ranked together with the criterion of BCR. Different alternatives for the infrastructure project can then be examined in the SAF. The work with the Long List and framework can be organised as a desk study, where different scenarios can be made use of to provide the decision support for a robust and feasible choice of the infrastructure alternative. However, the work with the Long List and the framework can also be organised as a decision conference where the influence of different stakeholder views (criteria selection and importance ordering) can be taken into account. In this presentation we concentrate on the framework based on a decision conference organised with the purpose of informing the analytical part.

The main elements of the SUSTAIN Appraisal Framework

Figure 3 below gives an overview of the elements in the SAF to be described.

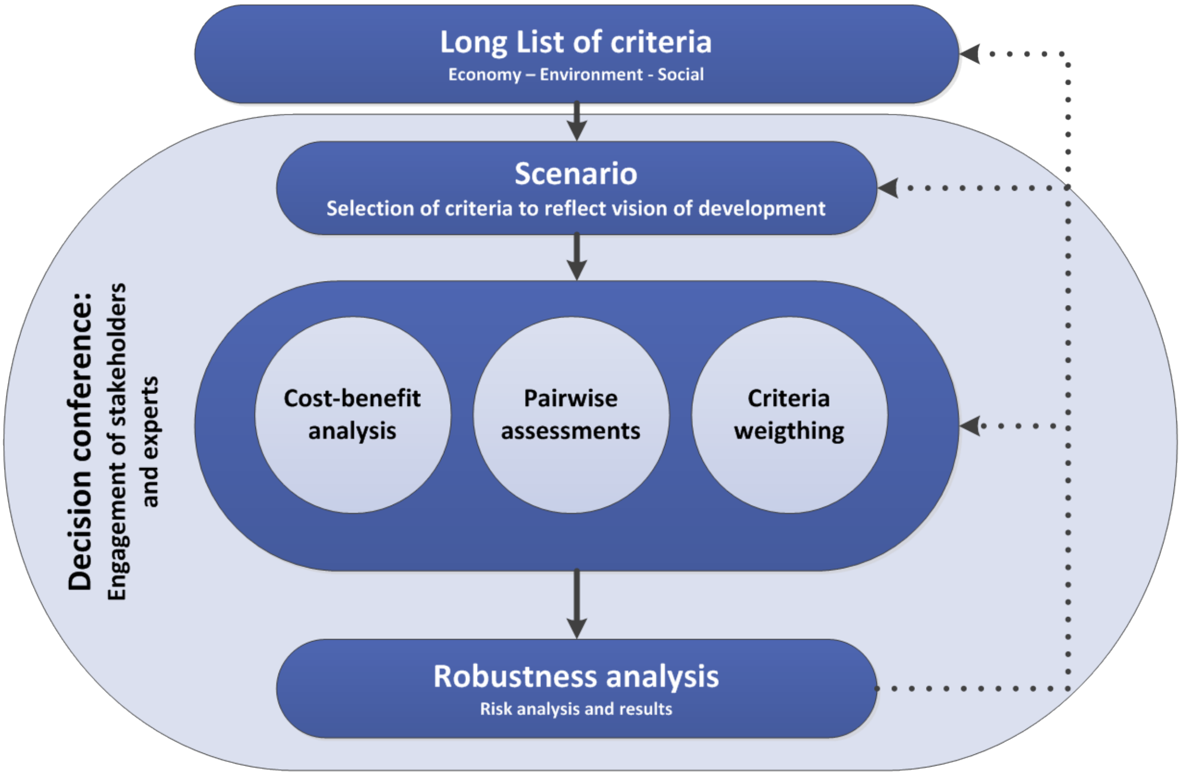

Figure 3 The SUSTAIN Appraisal Framework indicated by its main elements.

As presented in Figure 1 a generic overview of the transport planning process (a vision) together with understanding of the appraisal task lay behind the goals and objectives that inform both the determination and design of appropriate candidates or alternatives to enter the appraisal work. In the SUSTAIN Appraisal Framework the vision as described above is included as scenarios and in in this paper specifically as the BAU and SD scenarios.

Steps of the SUSTAIN Appraisal Framework

The SAF can be described as a number of steps beginning with the determination of a scenario-based Short List as the first step. As follows the procedure can be described by altogether 7 steps, where steps 1 to 6 are repeated until each scenario has been examined; in this case twice with the BAU and SD scenarios.

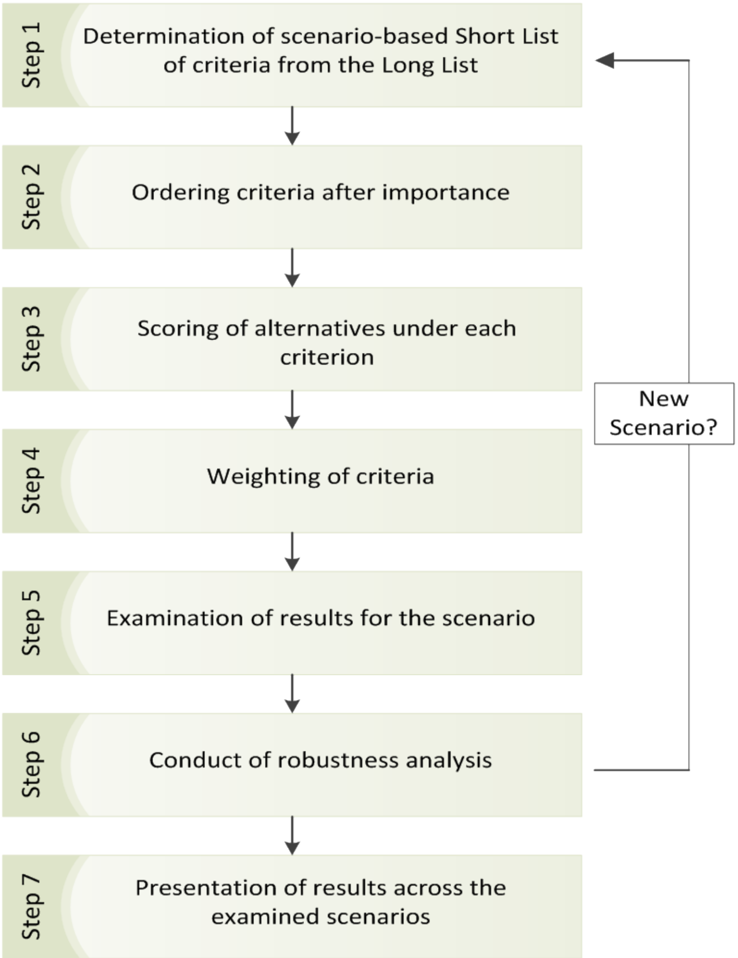

Figure 4 The 7 steps of the SUSTAIN Appraisal Framework

Given the Short List where the objectives – or MCDA criteria – are listed in alphabetical order the following task (step 2) serves to order the criteria after importance. Both step 1 and step 2 are based on the deliberations of the participants in the decision conference. The concept of a DC consists of three main components: group processes, decision analysis and information technology. The group processes are assisted by an impartial facilitator who is guiding the participants though the DC. The main task of the facilitator is to ensure that all the participants get a chance to express their opinions (Franco and Montibeller, 2010). The decision analysis is supported by the software model which is constructed and run by a decision analyst who on-the-spot collects the relevant data and judgments of the participants (Phillips and Bana, 2007). In principle, the model represents the collective view of the group at any point of time along the process allowing the participants to understand each step such that no black-box process/solutions should occur and only confident results be achieved (Jensen, 2012; Leleur, 2012).
As the criteria have been ordered after importance, the scoring of the alternatives under each of the criteria in the shortlist is performed. The relative scores of alternatives are determined

through the pairwise comparison mechanism, where the alternatives are compared two by two under each criterion and assigned with numerical values based on preference intensity (Jensen, 2012). The pairwise comparisons can be supported by quantitative information where available (e.g. the assessment of the CBA criterion is supported by the BCRs). In order to assess the total score for each alternative a weighting of the criteria is necessary. The criteria are weighted in step 4 using rank order distribution weights (ROD) embedded within the SMARTER approach (Edwards and Barron, 1994). It is assumed to be very difficult to make the participants agree directly upon a weight set of criteria. In addition to negotiated group weights the model also contains the possibility to examine all the different weight sets provided by each participant individually. Using SMARTER the participants of the DC place the criteria into an importance order: for example Criterion 2 (C2) is more important than Criterion 3 (C3) which is more important than Criterion 1 (C1) which is more important than Criterion 4 (C4), and so on, C2 ≥ C3 ≥ C1 ≥ C4... . The SMARTER approach then assigns surrogate weights to the criteria based on this ranking. A number of methods that enable such an ordering to be translated into surrogate weights have been developed. These are, among others, Rank Order Centroid (ROC), Rank Sum (RS), RR Rank Reciprocal (RR) and Rank Order Distribution (ROD) weights. Roberts and Goodwin (2002) have examined these methods in detail and found that ROD weights seem to provide the best approximation of the participants' preferences.
After deriving the separate scores for the alternatives within all the assigned criteria and furthermore having determined the weights for the criteria – it is possible to produce an appraisal result based upon the participants' input at the decision conference. These results for the scenario are examined in step 5.
In the framework the robustness analysis in step 6 is conducted by testing the sensitivity of the alternatives' total score for changes in the criteria weights. This is accomplished by performing an analysis using Monte Carlo simulation. The analysis consists of simulation with randomly generated criteria weights but at the same time preserving the importance order of criteria determined by the stakeholders or decision makers at the decision conference (Jensen, 2012). Furthermore for each criterion a weight stability interval is calculated based on Jimémez et al. (2004) who have described how these weight stability intervals can be implemented in a decision analysis tool. It is assumed that the weights assessed by the stakeholders or decision-makers are valid as preference representation. Thus with some uncertainty the simulation can identify the critical criteria where a change of weight can result in a different ranking of the alternatives. This information can be useful, especially in the public decision domain where there often is a need to justify the decision for the public.
Once all scenarios have been examined and total scores for all alternatives in each scenario are available it is possible to present the results across the examined scenarios in step 7.

DEMO-CASE ILLUSTRATION OF THE FRAMEWORK

The SUSTAIN Appraisal Framework supports the implementation of various scenarios which can be examined. Each scenario can include different criteria, and a full overlap of the criteria among the scenarios is not necessary. In the following the framework is illustrated on the Rail Baltica case.

Rail Baltica

The Baltic countries consist of Estonia, Latvia and Lithuania and together they muster a population of approximately 6.5 million inhabitants. The Baltic countries are former members of the Soviet Union and hence transport flows are mainly concentrated on east-west connections rather than north-south. In 2004 the three Baltic countries and Poland became members of the European Union and have since then changed their image from being Eastern European countries to being Northern European. The Rail Baltica project aims at ensuring a safe, fast and high quality connection between the Baltic States and the major economic, administrative and cultural centres of Western Europe (AECOM, 2011). The Baltic rail system is currently incompatible with mainland European standards, thus the goal is to link Helsinki – Tallinn – Riga – Kaunas – Warsaw continuing to Berlin (see Figure 5). Until, Estonia, Latvia and Lithuania joined the European Union, the issue was not considered a high priority. Now, within the European Union, there is a full consensus that the three countries need to be fully integrated into the wider European rail transport system.

Figure 5 An overview of the Rail Baltica corridor

Four alternatives have been identified based on considering various technical and environmental aspects (Ibid.).

Table 2 Four alternatives, distance, journey time and average speed (AECOM, 2011)

			Passenger / Freight		
Alternative	**Construction costs (Mill. €)**	**Benefit-cost ratio**	**Distance – (km)**	**Journey time (hrs.)**	**Ave. speed (km/h)**
Alt. 1	4,882	1.75	701 / 708	4h08m / 10h23m	170 / 68
Alt. 2	5,077	1.26	788 / 804	6h08m / 11h34m	128 / 70
Alt. 3	5,508	1.40	791 / 792	4h49m / 11h10m	165 / 71
Alt. 4	5,328	1.07	858 / 859	6h44m / 11h53m	127 / 72

The four alternatives have been designed and selected because of being (AECOM, 2011):

- Alt. 1 - the most direct and shortest route
- Alt. 2 - the most direct existing rail route
- Alt. 3 – best of maximising potential passenger demand by passing through the majority of the major cities
- Alt. 4 – best at utilizing the existing networks

From the results of the CBA Alt. 1 should be the preferred alternative with a BCR on 1.75 (above 1.0 indicates a socio-economic feasible project). However, an important appraisal question, and the rationale behind the formulation of the SUSTAIN Appraisal Framework, is: Are there any strategic elements that are not included in the CBA, which could provide an argument for selecting another alternative?

Assessment of the alternatives

In the following the appraisal of the four alternatives of the Rail Baltica will be described by the steps of the SUSTAIN framework. Because of limited space only the results from the SD scenario are described in detail; however the results from both the BAU and SD scenario will be compared as the last step within the framework.

Step 1

In the first step the Short Lists are determined as representing two visions of the future development were formed – a business as usual scenario (BAU) and a sustainable development scenario (SD).

Step 2

In the following step 2 the criteria have been ordered in accordance with the importance that the participants in the decision conference have agreed upon, see Table 3.

Table 3 Criteria selection for the two scenarios - in prioritised order

Business as usual (BAU scenario)	Sustainable Development (SD scenario)
A.4 Free movement of goods	B.2 Climate and global warming
C.9 Transport network and accessibility	B.4 Existing assets and resources
B.2 Climate and global warming	C.1 Accessibility by public transport
Cost-benefit analysis	A.6 Int. ties and coherence between countries
C.4 Labour market and socio-geographic job distribution	A.1 Competition on transport markets
A.6 Int. ties and coherence between countries	C.8 Townscape and land-use aesthetics
B.5 Local air pollution and air quality	C.6 Social inclusion and participation
B.6 Noise	Cost-benefit analysis

Step 3

Figure 6 presents the results from the pairwise comparisons made in the SAF. From the SD-scenario it is evident that Alt. 1 and 4 performs the best where Alt. 1 has the highest assessment score for the criteria: Climate and global warming (B.2), Social inclusion and participation (C.6) and the resulting BCR from the conventional CBA. Alt. 4 performs the best within: Existing assets and resources (B.4), Accessibility by public transport (C.1), International ties and coherence between countries (A.6) and Townscape and land-use aesthetics (C.8). Alt. 3 only performs the best within the criterion Competition on transport markets (A.1), whereas Alt. 2 based on this initial stage should be withdrawn from further analysis.

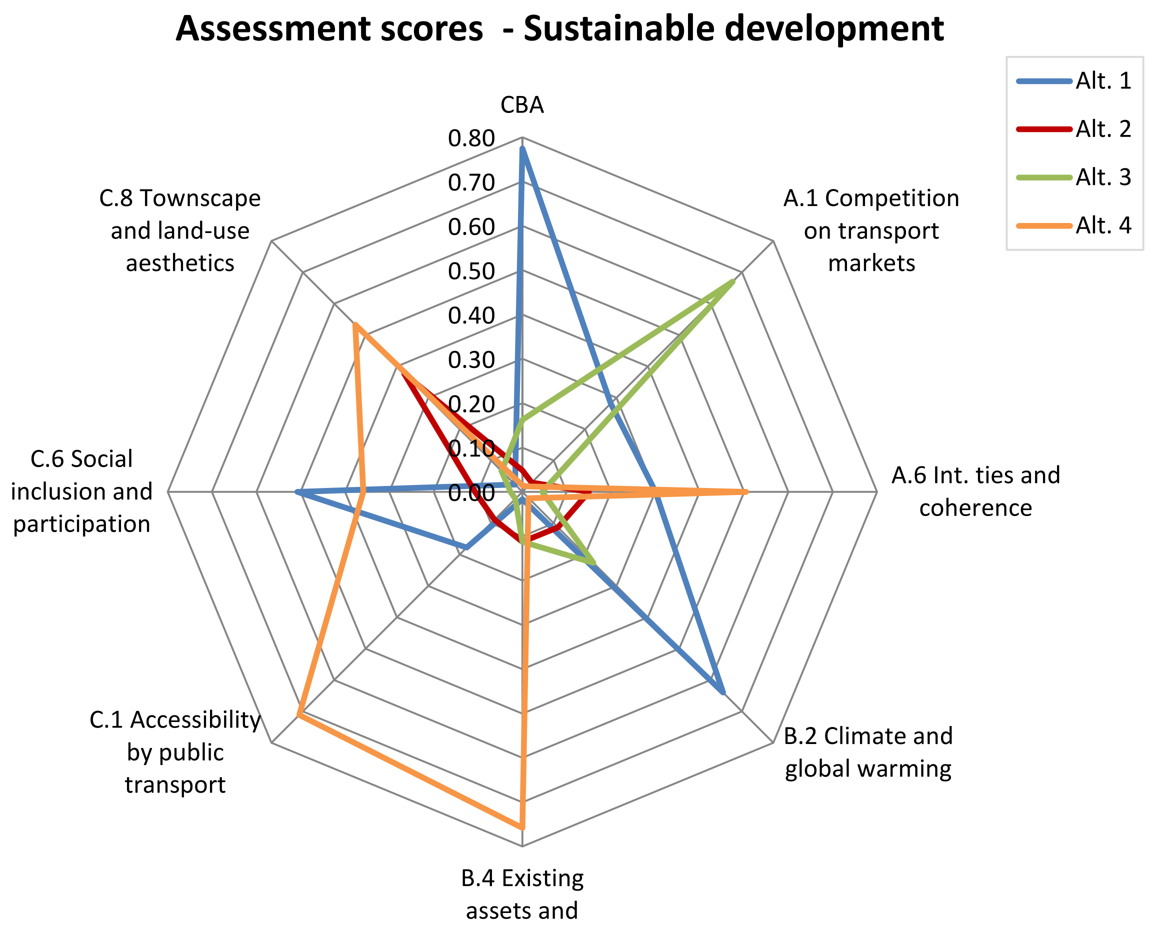

Figure 6 Assessments scores for the four alternatives under all the included criteria in the SD scenario. The scale, here going up to 0.8, is based on the actual range of the assessment scores

The BAU scenario produces the same type of results (Figure 7). From the BAU scenario it is evident that Alt. 1 performs the best. Alt. 1 is assessed to perform best on five criteria, which are: CBA, Free movement of goods (A.4), International ties and coherence between countries (A.6), Climate and global warming (B.2) and Noise (B.6). Alt. 4 only performs best on two of the criteria. Alt. 2 perform best on Local air pollution and air quality (B.5) and tie with Alt. 1 for the best score on International ties and coherence (A.6), while Alt. 3 only is assessed with a top score on Noise (B.6) in tie with Alt. 1.

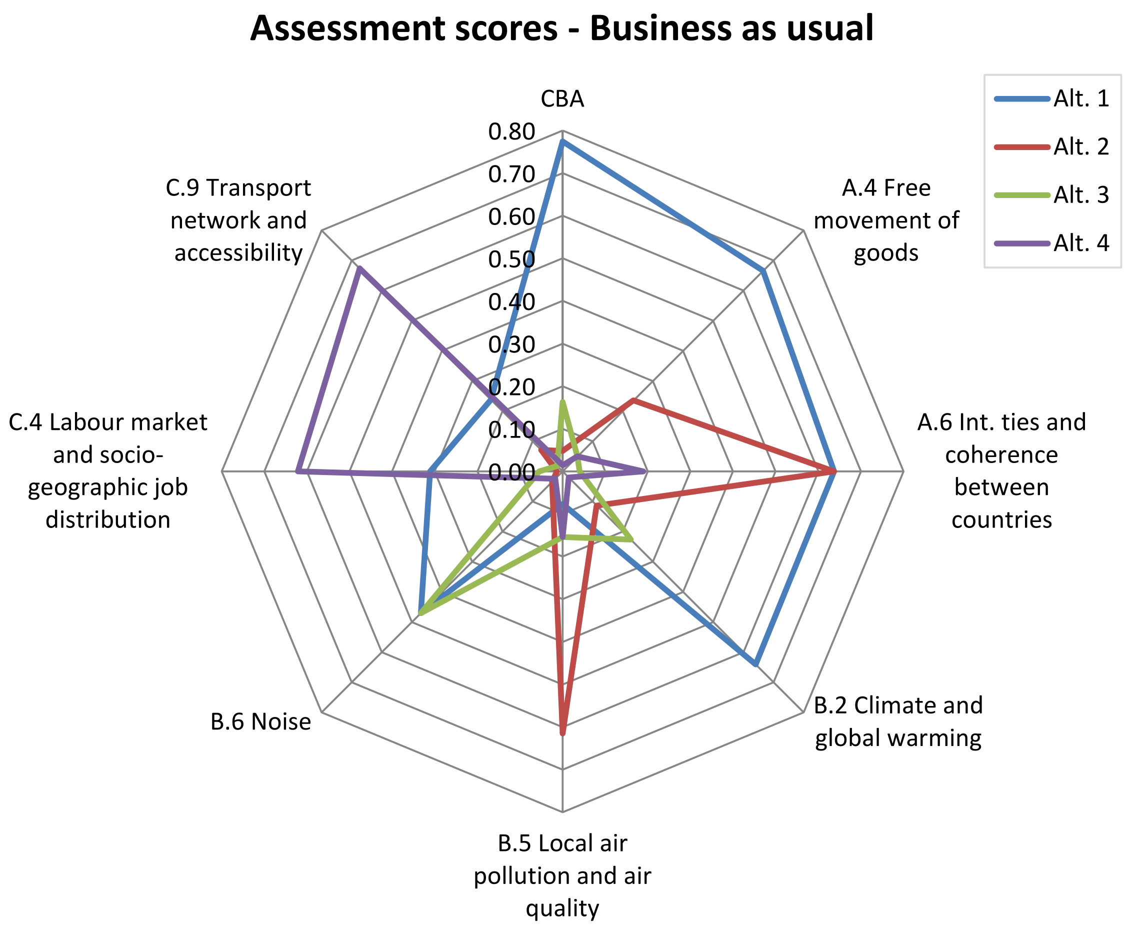

Figure 7 Assessments scores for the four alternatives under all the included criteria in the BAU scenario

Step 4

In step 4 the criteria are assigned a ROD weight according to the importance ordering performed in step 2. The allocation of weights on the three sustainability dimensions is presented in Figure 8 which illustrates that all of the three dimensions are well represented in the SD scenario – although with a higher emphasis on the environmental dimension, while in the BAU scenario there is not unexpected a higher emphasis on the economic dimension.

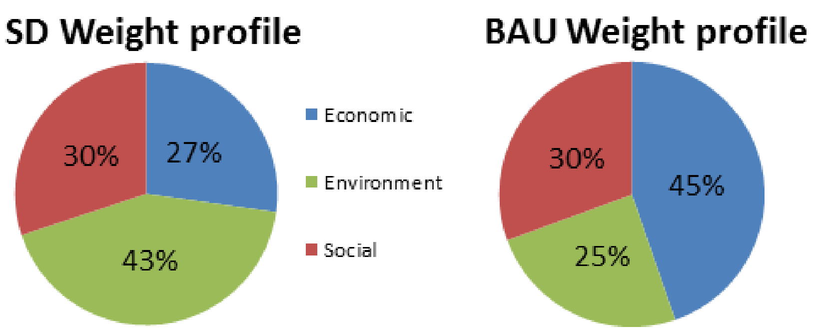

Figure 8 Allocation of weight on the three dimensions of sustainability for the two scenarios

Step 5

Hereafter, step 5 presents the results for the scenario where the ROD weights and the various assessment scores are transformed into single, aggregated total scores for each alternative. Evidently, as illustrated in Figure 9, a sub-division has been made for each alternative depicting a total score respectively for the pool of criteria under the economic, environmental and social pillar.

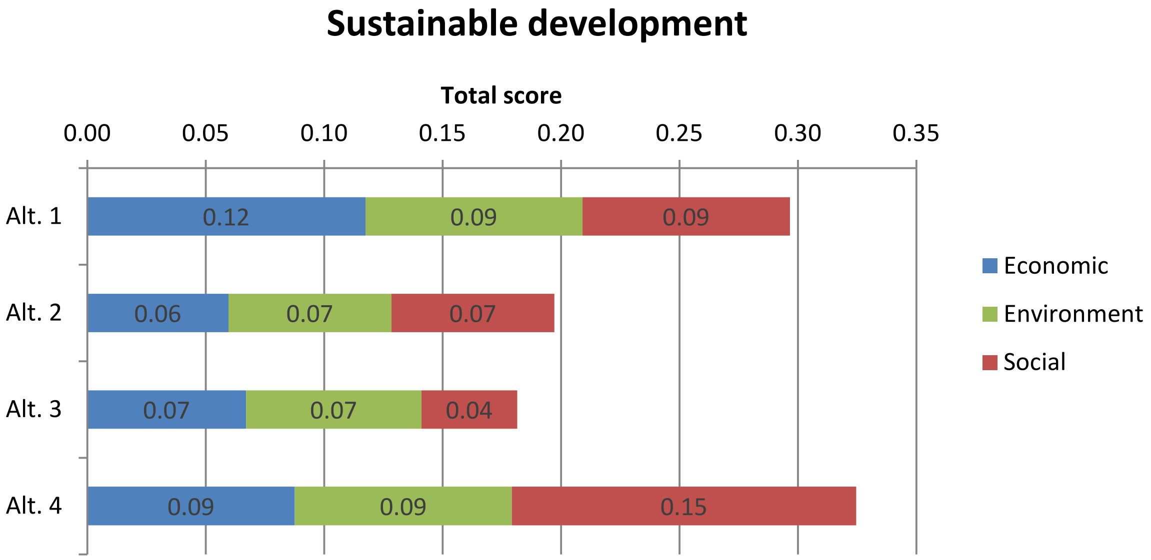

Figure 9 Total scores for the alternatives in the SD scenario

For the case of the Rail Baltica, as examined here, the results for the SD-Scenario revealed that Alt. 4 was appraised as having the highest total score, however, with Alt. 1 performing almost as well. One main result from such an analysis is that Alt. 2 and 3 should not be implemented based upon the previous steps.
The splitting of the total scores for the four alternatives in the three dimensions of sustainability, as illustrated in Figure 9, gives valuable information to the decision-makers on how well each of the alternatives performs within each dimension.

Step 6

Evidently, seeking to identify the best possible alternative for implementation, a robustness analysis is introduced in order to clarify whether one alternative is more robust to changes than the others. In step 6 the robustness analysis is conducted by testing the sensitivity of the alternatives' total score for changes in the criteria weights. The analysis consists of a Monte Carlo simulation with randomly generated criteria ROD weights while all the time preserving the importance order of criteria determined by the stakeholders or decision makers at the decision conference. The result from this sensitivity analysis is presented in Figure 10.

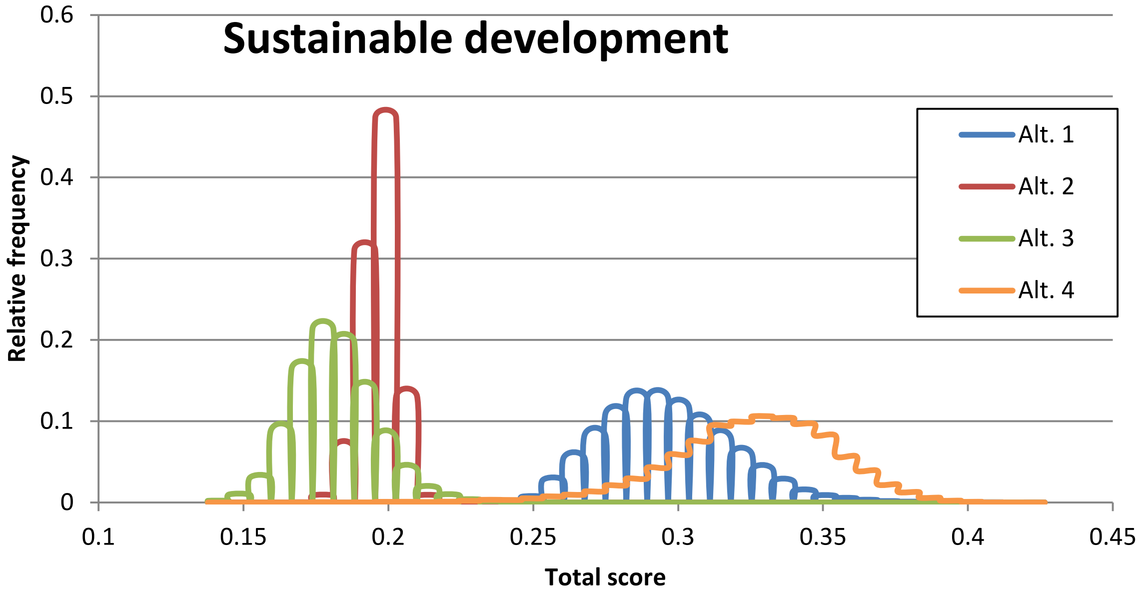

Figure 10 Results from sensitivity analysis on the criteria weights

The results illustrated in Figure 10 supports the previous conclusions that Alt. 2 and 3 will not be able to match the total scores of either Alt. 1 or 4 with the established order of importance of the criteria. At the same time the result reveals that there is a higher probability for Alt. 4 to achieve a higher total score than Alt. 1. However, it is also clear that there is a large overlap of scores between Alt. 1 and Alt. 4, which indicates that both alternatives can become top ranked.

A more detailed analysis of sensitivity can be performed by the so-called weight stability intervals. For the SD-Scenario the weight stability intervals are presented in Figure 11. An interval which has a low value equal to 0 indicates that if the criterion would be set to 0 (same as omitting the criterion from the analysis), it would not alter the final ranking of the alternatives. This applies to the criteria CBA, Competition on transport markets, Climate and global warming and Social inclusion and participation. While an interval with an upper value equal to 1 indicates that not even if the criterion was the only criterion would it lead to a change in the final ranking of the alternatives. This applies to the criteria International ties and coherence and Accessibility by public transport.

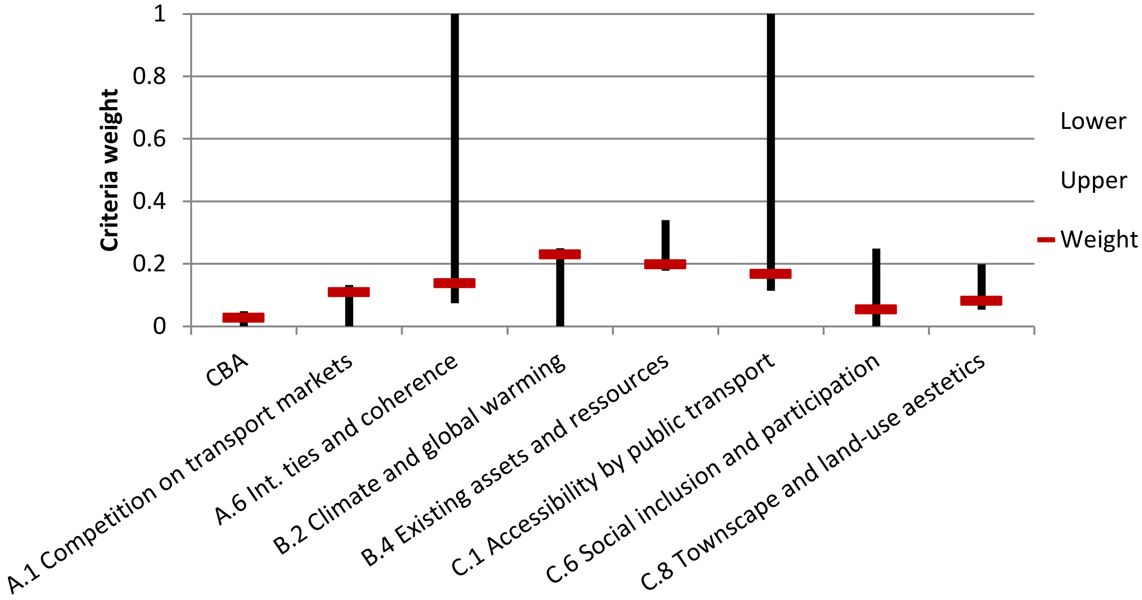

Figure 11 Weight stability intervals for the criteria in the SD scenario

As there is no Lower-Upper range equal to [0;1] the weight stability interval analysis reveals that the total ranking of all four alternatives are sensitive to changes in all of the criteria weights. Generally short ranges indicate high sensitivity.

Step 7

The final step within the SAF is to compare the two sets of results from the SD and the BAU scenarios (cf. Figure 12).

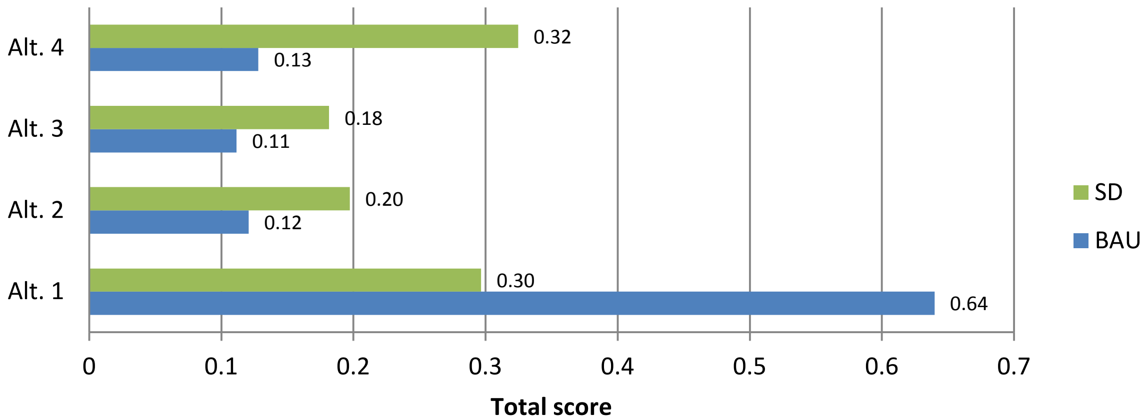

Figure 12 Total scores for the four alternatives

Evidently, the comparisons of results show that while Alt. 1 is the most favourable alternative in the BAU scenario the picture is less clear in the SD scenario. Actually, Alt. 4 is getting a slightly higher score than Alt. 1 in the SD scenario. However, the robustness analysis of the SD scenario reveals that this ranking is highly sensitive as only minor changes in the weighting on several of the criteria can tip the result.
The presentation of results across the scenarios can be carried out not just for the consensus-values given as input to the analytical modelling but also for each of the stakeholders represented based on their input when not being affected by seeking to make consensus compromises.

CONCLUSION

When analysing the results obtained in the case example it can be noted that by using scenarios or visions of development it is possible to describe and assess how the different alternatives perform under different settings. The case study reveals that while Alt. 1 was outperforming all of the other alternatives in the BAU scenario, the picture was less clear in the SD scenario. Furthermore, the presentation of the performance of the alternatives under each criterion (as shown in Figure 6) provides possibilities for the decision-makers to directly compare how the different alternatives perform without applying the at times critical criteria weights. Determining the weights for each criterion is handled by using importance order, more specifically the ROD weight methodology. Giving explicit information to the decision-makers on the composition of the weight profile (as shown in Figure 8) provides valuable information on how the three dimensions of sustainability are represented in the scenarios.
A key concern with the SUSTAIN Appraisal Framework is to identify the effective means for sustainable transport planning. This complex challenge can be met as concerns appraisal methodology with an approach, which involves MCDA to embrace various and often conflicting criteria and robustness analysis for taking into account the interests and preferences of different stakeholders.
The SUSTAIN Appraisal Framework approach has the advantage of making conflicting views among stakeholders and/or decision-makers more explicit, thereby permitting better monitoring. In MCDA, distributional issues are made explicit since the processes of allocating weights and scores are separated. Decision-makers are therefore free to choose criteria from the Long List of criteria and give relatively more weight to the criteria they consider important. Distributional conflicts can be addressed in MCDA through extensive robustness analysis for the weights. Sensitivity analysis can contribute to conflict reduction and the creation of an institutional state of equilibrium, whereby economic goals, broader social objectives and environmental considerations all feature prominently (De Brucker et al., 2013).
The SUSTAIN Appraisal Framework has been set out to make it possible to conduct appraisal studies based on a comprehensive range of objectives relevant for national sustainable transport planning (NSTP). As demonstrated by the case example it can be used in a flexible way and adapted to the specific appraisal problem. The case concerns a classical type of study in transport planning as regards infrastructure projects but it can be noted that the SUSTAIN research project aims at appraising also policies and interventions

of different kind; however this will take place later in the SUSTAIN research work that will continue until 2016. The Long List will be further developed in the SUSTAIN project in accordance with experience from its application and the availability of research results from the Indicator part of SUSTAIN. No doubt the SUSTAIN Appraisal Framework as presented in its initial version in this paper can be elaborated and refined, when more case studies have been examined and the Long List of criteria has been modified based on the further study of national sustainability indicators sets also part of the SUSTAIN research work.

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