REFERENCE SCENARIO FORECASTING: A NEW APPROACH TO TRANSPORT PROJECT ASSESSMENT

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KEYWORDS

Decision support systems, reference class forecasting, Optimism Bias, risk analysis, cost-benefit analysis, reference scenario forecasting

ABSTRACT

This paper presents a new approach to transport project assessment in terms of feasibility risk assessment and reference class forecasting. Normally, transport project assessment is based upon a cost-benefit approach where evaluation criteria such as the net present value and the benefit cost ratio are obtained. Recent research has however proved that substantial inaccuracies are present when obtaining the monetary input to the cost-benefit analysis, particularly as concerns the construction costs and demand forecasts. This paper proposes a new approach in order to address these inaccuracies in a so-called reference scenario forecasting (RSF) frame. The RSF is anchored in the cost-benefit analysis (CBA); thus, it provides decision-makers with a quantitative mean of assessing the transport infrastructure project. First, the RSF method introduces uncertainties within the CBA by applying Optimism Bias uplifts on the preliminary construction cost estimates. Hereafter, a quantitative risk analysis is provided making use of Monte Carlo simulation. This stochastic approach facilitates random input parameters based upon reference class forecasting, hence, a parameter data fit has been performed in order to obtain validated probability distribution functions. The latter have been placed and ultimately simulated on the inaccuracies of determining demand forecasts, i.e. leading to the travel time savings and ticket revenues of the project. Finally, RSF makes use of scenario forecasting where trend scenarios such as economic growth and level of cross-border integration are investigated. The latter was relevant as RSF is demonstrated by a case example concerning the fixed link between Elsinore (Denmark) and Helsingborg (Sweden) in which the calculations are performed in the newly developed UNITE-DSS decision support model.

INTRODUCTION

This paper lays out a new approach to the assessment of transport infrastructure projects in terms of evaluating the embedded model uncertainties. Conventional transport infrastructure project assessments are based upon cost-benefit analyses in order to appraise whether the project is feasible or not in terms of net present values (NPV), benefit cost ratios (BCR), etc. Recent research (e.g. Salling (2008) and Salling & Banister (2009)) proved that the point estimates derived from such analyses are embedded with a large degree of uncertainties. Thus, a new scheme has been introduced in terms of applying quantitative risk analysis (QRA) and Monte Carlo simulation in order to represent the uncertainties within the cost-benefit analysis (CBA).

Moreover, the QRA technique is supplemented with reference class forecasting (RCF) which depicts the historical tendency of overestimating transport related benefits (user demands i.e. travel time savings) and underestimating investment costs (Flyvbjerg et al., 2003; Flyvbjerg, 2007). RCF is based on prospect theory where Nobel Laureate Professor Emeritus Daniel Kahneman together with the late Professor Amos Tversky described decisions between alternatives that involve risk, i.e. alternatives where the general outcome is uncertain but the associated probabilities are known (Kahneman and Tversky, 1979). The RCF technique implies a compilation of past projects similar to the one being appraised in order to compare the deficiencies/biases. Thus, the RCF technique relies on a pool of past projects in order to form a reference class similar to the project under assessment. Flyvbjerg et al. (2003) investigated a set of reference classes depicting inaccuracies in the investment costs predictions. From these classes they developed a set of uplift values (in percentage) to be placed on the preliminary investment denoted as Optimism Bias uplifts (Flyvbjerg and COWI, 2004).

Salling (2008) investigated a large pool of reference classes elaborated in Flyvbjerg et al. (2003) where two types of probability distribution functions (PDFs) have been determined in terms of a Beta-PERT distribution for the overestimation of benefits and an Erlang distribution for the underestimation of Investment costs. The latter two transport related impacts make up the key components in most transport evaluation schemes for which reason the remaining impacts within the CBA are considered “certain” (Leleur, 2000). This paper, however, only investigates the overestimation of benefits in terms of applying PDFs whereas the underestimation of investment costs are assessed solely by the use of Optimism Bias uplifts as presented above.

Reference scenario forecasting (RSF) is referred to as the combination of RCF and QRA brought together in a scenario-grid. The latter represents a set of exploratory scenarios relying on the case study to be investigated (Salling and Leleur, 2009). The modeling frame will be operationalised by introducing a new version of a previously designed decision support model, CBA-DK (Salling 2008; Salling and Banister 2010), adopted for combining CBA and QRA, the UNITE-DSS model. The variation between scenarios will systematically be explored and related to the scenario-grid. The specific scenario input is assessed by making use of the triple estimation technique (Lichtenberg 2000) returning a minimum and maximum boundary corresponding to the shape of the Beta-PERT distribution. The RSF scenario grid of 3x3 encompasses a focal scenario 5 provided by the CBA together with Optimism Bias uplifts and QRA. The remaining 8 scenario inputs are determined based upon stakeholder and decision-maker involvement. Hence, a final set of altogether nine scenarios is obtained. In addition to the actual RSF calculations the paper discusses its relevance as decision support for transport decision making with an explicit concern of project uncertainties and feasibility risk assessment.

This paper is disposed as follows. After this short introduction a case description is made depicting the case study of connecting the Northern part of Zealand in Denmark (Elsinore) with the Southern Region of Sweden, Skane (Helsingborg). Subsequently the UNITE-DSS decision support model is introduced together with preliminary results from a deterministic run within the model. A small section describes the use of the Optimism Bias uplifts that are applied on the investment costs of the case alternatives. Hereafter the methodological approach of reference class forecasting is explained with special emphasis on the demand forecasts which make up the travel time savings and ticket revenue effects included in the cost-benefit analysis. Then the reference scenario forecasting approach is introduced with a set of exploratory scenarios. The stochastic result is presented in terms of certainty graphs and index values which function as risk-related decision support for the assessed transport infrastructure project. The final section gives a conclusion and a perspective on the further research.

THE CASE STUDY

The Oresund Fixed Link connecting the greater area of Copenhagen with Malmo in Sweden opened in July 2000. Today, ten years after the opening, the railway line of the link is close to capacity resulting in delays and discomfort for the travellers. The case of this paper concerns a new complementary fixed link connection between Denmark and Sweden between the cities of Elsinore (Helsingor) and Helsingborg. Regionally, the proposed connection is expected to create a substantial increase in trade, education and work place related benefits. Ultimately it is expected that a fixed link with increased commuter traffic across the border will result in a common labour and residence market. In addition, the recent decision to construct the Femern Belt fixed link connecting Denmark with Germany will increase the number of travellers from central Europe through Denmark to the rest of Scandinavia (Sweden, Norway and Finland). This means further traffic to cross the Oresund (Larsen and Skougaard, 2010).

The case is commonly referred to as the HH-Connection (see Figure 1) and has been examined since the 1980s where the first alignment proposals were suggested. The opening of the Oresund fixed link between Copenhagen and Malmo, however, postponed the HH-Connection but now its implementation is recommenced as explained. In Figure 1 the circle shows the proposed new fixed link located approximately 50 km north of the existing fixed link across Oresund.

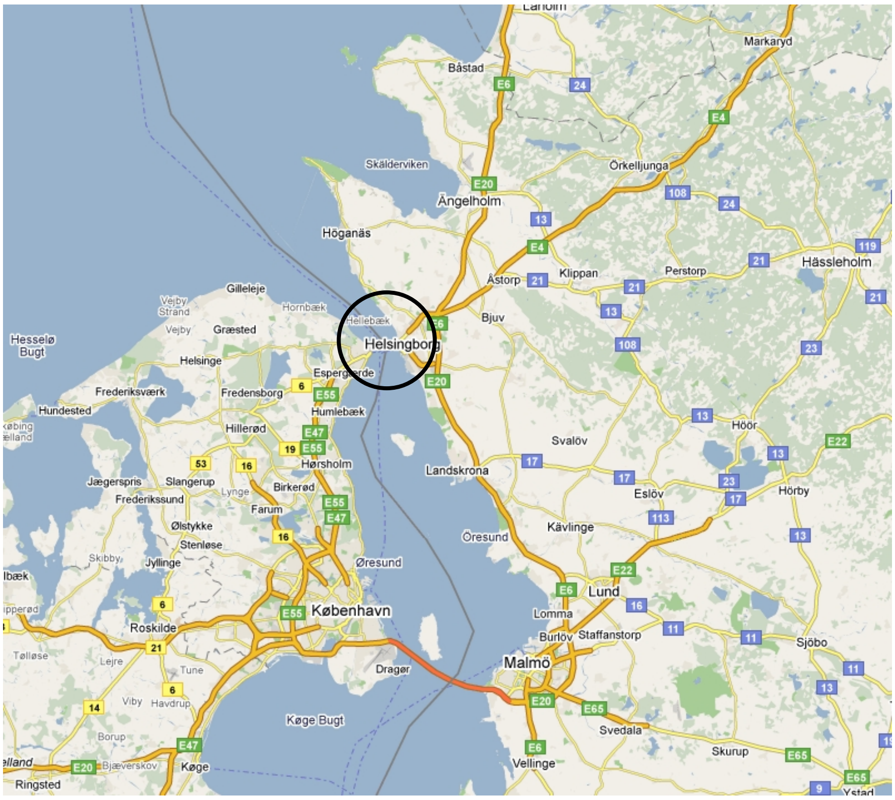

Figure 1 *– The proposed new fixed link between Elsinore (Helsingor - Denmark) and Helsingborg (Sweden): the HH-Connection (from Google Maps)*

The current situation with ferry service is referred to as the base scenario where the proposed alternatives will substitute the ferries with a fixed link where four alternatives are considered, see Table 1.

Table 1 *– The proposed four alternatives for the HH-Connection with construction costs in million DKK (adapted from Larsen and Skougaard, 2010)*

HH-Connection (alternatives)	Description (Alignment of connection)	Cost (million DKK)
Alternative 1	Tunnel for rail (2 tracks) person traffic only	7,700
Alternative 2	Tunnel for rail (1 track) goods traffic only	5,500
Alternative 3	Bridge for road and rail (2x2 lanes & 2 tracks)	11,500
Alternative 4	Bridge for road (2x2 lanes)	6,000

The following section describes the UNITE-DSS decision support model, made use of in order to assess the above four proposed alternatives in a socio-economic perspective. The model is composed of four modules (I-IV) where the first two comprise deterministic calculations in terms of a cost-benefit analyses and Optimism Bias uplifts and the final two comprise stochastic calculations in terms of quantitative risk analyses (QRA) respectively in terms of reference class forecasting (RCF) and reference scenario forecasting (RSF).

THE UNITE-DSS DECISION SUPPORT MODEL

The UNITE-DSS decision support model is designed to bring informed decision support both in terms of single aggregated estimates such as the NPV and BCR but also in terms of interval results by accumulated probability curves. The current interaction between the deterministic and stochastic part of the UNITE-DSS model aims to explore the feasibility risk highly relevant when assessing transport infrastructure projects. The software model is anchored on a Microsoft Excel platform with the CBA methodology following the Danish Manual for Socio-Economic Analysis (DMT, 2003). Such type of analysis is often assigned with a substantial degree of uncertainties especially as concerns the investment costs of the transport project for which reason Optimism Bias uplifts have been applied within the modelling framework. The methodologies of CBA and Optimism Bias uplifts make up the deterministic procedure of the UNITE-DSS model.

The stochastic procedure of the model is based upon the @RISK software developed by Palisade Corporation as an add-in to Microsoft Excel (Palisade, 2007). Even though the deterministic procedure introduces risks and uncertainties in terms of uplifts to the investment costs, another key impact within the CBA which is necessary to consider are the travel time savings (and ticket revenue). By applying RCF and QRA in terms of Monte Carlo simulation, this impact is explored in the modelling scheme in terms of probability distribution functions (PDFs).

Finally as part of the stochastic procedure a scenario forecasting module is applied in order to assess future-oriented trends such as economic development, levels of integration, etc. Currently, trend scenarios are defined in the UNITE-DSS model by varying the inputs from the travel time savings effect, i.e. increasing or decreasing the benefit stemming from the determined PDF (Lichtenberg, 2000; Salling and Leleur, 2009). This methodological approach seen as an innovative feature of the model has been formulated as reference scenario forecasting since it builds upon the two concepts of RCF and scenario forecasting.

A flow chart of the UNITE-DSS model in its current version is depicted in Figure 2. After each of the four module calculations, a result can be derived anchored within the cost-benefit analysis. The two stochastically based results are furthermore producing so-called certainty graphs and certainty values illuminating the socio-economic cut-off value with regard to feasibility, i.e. benefit cost ratios (BCR) ≥ 1.00.

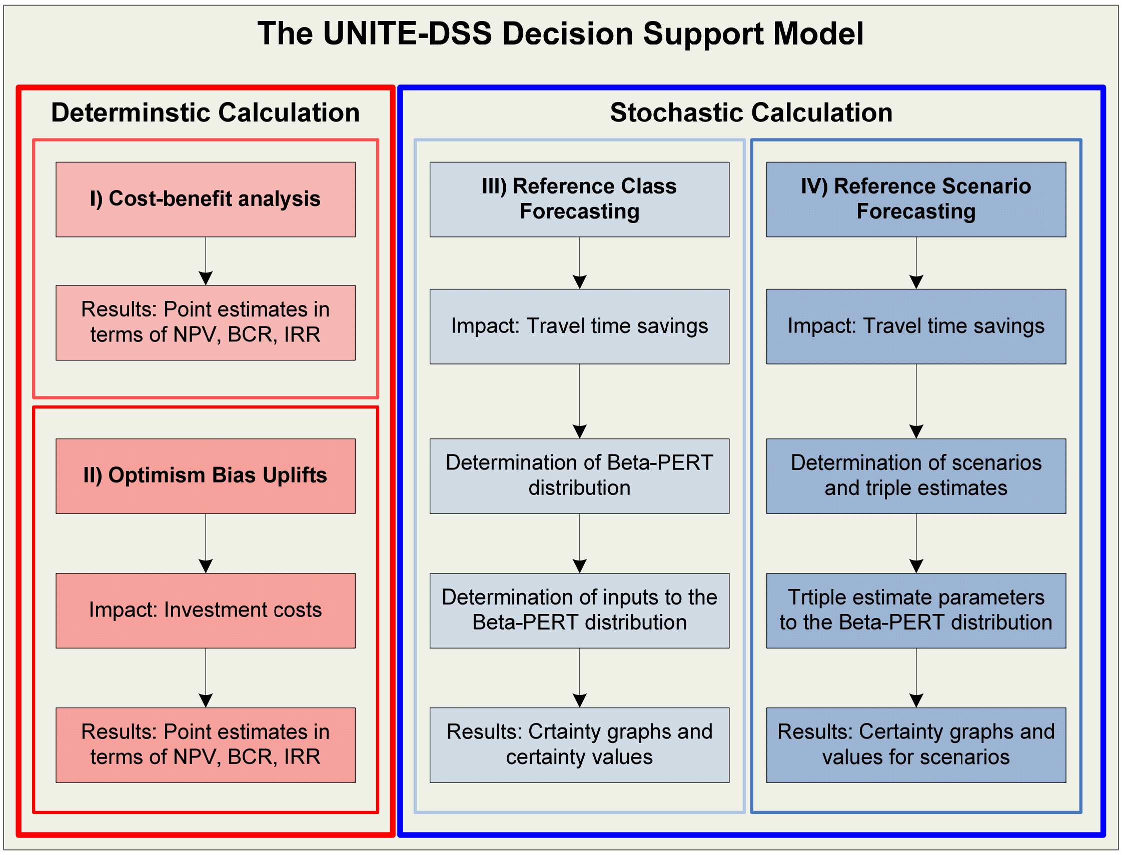

Figure 2 *– Calculation procedure for the UNITE-DSS model*

Cost-benefit analysis

Cost-benefit analysis seeks to determine whether or not a certain output shall be produced and, if so, how best to produce it (Dasgupta and Pearce 1978; Leleur, 2000). The method relies solely on the estimation of related impacts/effects of the project being examined and on validated unit prices made use of. The UNITE-DSS model applies a set of Danish unit prices and the guidelines formulated by the Danish Ministry of Transport (DMT, 2003). Inputs to the CBA are shown in Table 2 consisting of construction costs (coast-to-coast construction), operating and maintenance, ticket revenue, travel time savings, vehicle operating costs and emissions (note that 1 mio. DKK ≈ €130,000).

Table 2 *– CBA impacts for the assessment of the HH-Connection project (adapted from Larsen and Skougaard, 2010)*

Impact	Alt. 1	Alt. 2	Alt. 3	Alt. 4
Construction costs (mio. DKK)	-7,700	-5,500	-11,500	-6,000
Terminal value (mio. DKK)	418	298.6	924.3	325.7
Operating and Maintenance (mio. DKK/year)	-154	-110	-230	-120
Travel Time savings (mio DKK/year)	291.6	161	413.6	272.4
Vehicle Operating costs (mio DKK/year)	-32.3	-12.4	-89.3	-50.8
Ticket Revenue (mio DKK/year)	390.2	11.2	961.3	763.1
Emission benefits (mio DKK/year)	275.1	-13.5	3,345	3,082

The UNITE-DSS model initially produces evaluation criteria in module I) in terms of BCRs and NPVs, see Table 3.

Table 3 *– Results from the initial deterministic run of the UNITE-DSS model (based upon data material from Larsen and Skougaard, 2010)*

HH-Connection (alternatives)	Cost (million DKK)	BCR	NPV (million DKK)
Alternative 1	7,7	1.15	1,8
Alternative 2	5,5	0.39	-5,1
Alternative 3	11,5	2.17	20,3
Alternative 4	6,0	2.63	17,8

The results in Table 3 depict three feasible project alternatives, i.e. alternatives 1, 3 and 4. The two bridge solutions clearly perform the best with high BCRs whereas alternative 2 with only one track for railway goods is performing poorly. Furthermore, for alternative 3 and 4 it should be noticed that with regard to the NPVs alternative 3 performs the best, while as concerns the BCRs alternative 4 performs the best.

REFERENCE CLASS FORECASTING

Traditionally transport infrastructure projects tend to be underestimated in terms of construction costs, deliberately or otherwise. Such underestimated costs for obvious reasons affect the overall assessment of the project in terms of its feasibility. Four categories of explanations for the underestimation of investment costs are given as technical, economic, political and psychological (Cantarelli et al., 2008). The technical explanation can be defined as forecasting errors rooted in imperfect techniques, inadequate data, honest mistakes, inherent problems in predicting the future and lack of experience. The economic explanation is rooted in terms of economic ‘self-interest’ or in terms of public interest resulting in *deliberate* underestimation. Political explanations assume strategic misrepresentation when forecasting the outcomes of projects as the main reason for cost overruns also denoted as pessimism bias (Næss et al., 2006) and finally, the psychological explanations are rooted in planning fallacy and optimism bias. For a thorough discussion of estimation uncertainty and related factors of influence we refer to Osland and Strand (2010). Below we focus on methodology to set out the principles behind the UNITE-DSS model.

The Optimism Bias approach is dealt with by the use of a well-established technique named reference class forecasting (RCF). The theoretical background to RCF originates in prospect theory developed by Kahneman and Tversky as part of a psychology study on human judgments (Kahneman and Tversky, 1979). A reference class denotes a pool of past projects similar to the one being appraised. A systematic collection of differences between forecast and actual values is gathered for a range of similar projects, the deficiencies in the forecast process (for costs and demand) are compared, and this evidence is then used to improve current decisions. Experience from past projects is then collected, compared and used so that “planning fallacy” can be avoided (Buehler et al., 1994). Subsequently, the main area of interest is to collect and analyze a set of reference classes in order to facilitate the uncertainty (or bias) embedded within a transport related impact. The British Department for Transport issued a guidance report in 2004 elaborating upon the latter establishing so-called percentage uplifts to be applied on construction costs estimates before entered in a decision support model (Flyvbjerg and COWI, 2004). Thus, the Optimism Bias uplifts should be applied to the estimated budget costs at the time of decision to build and they are referred to as the cost overruns calculated in fixed prices.

Optimism Bias uplifts

These deterministically derived Optimism Bias uplift values are implemented concerning the construction costs of the different alternatives for the HH-Connection within UNITE-DSS and a new set of evaluation criteria can be derived. Table 4 presents some of the uplifts applicable within transport infrastructure projects for different levels of certainty ranging from 50-90% (Flyvbjerg and COWI, 2004). The three main categories of road, rail and fixed link are covering a huge variety of different projects, i.e. road projects are for example divided into different reference classes comprising motorways, trunk roads, local roads, bus lane schemes etc. Rail projects have been divided into metro projects, light rail projects, high speed rail projects etc. whilst the fixed link category also covers bridges and tunnels.

Table 4 *– Optimism Bias uplifts (adapted from Flyvbjerg and COWI, 2004)*

Level of acceptable Optimism Bias	50%	60%	70%	80%	90%
Road	15%	24%	27%	32%	45%
Rail (and air)	40%	45%	51%	57%	68%
Fixed Links	23%	26%	34%	**55%**	83%

Hence, if a group of decision-makers decides that the risk of a cost overrun must be less than 20% for a road type project, the construction cost estimate must be uplifted by 32%. Thus, if the initial estimate was 100 mio DKK the final cost estimate taking into account the Optimism Bias at an 80% probability level would be 132 mio DKK. The specified acceptance level corresponds to the decision-makers risk aversion of the project, i.e. it is assumed that the decision-makers allow a 20% threshold that the project will be exceeding its budget. Thus, module II) produces a new set of BCRs for the project alternatives (Table 5) with 80% certainty as concerns cost estimate.

Table 5 *– Results from a deterministic run of the UNITE-DSS model applying the Optimism Bias uplifts with 80% certainty*

HH-Connection (alternatives)	Cost (uplifted) (million DKK)	BCR (orig.) (from Table 3)	BCR (uplifts): 55% uplift
Alternative 1	14,7	1.15	0.93
Alternative 2	10,5	0.39	0.33
Alternative 3	22,0	2.17	1.73
Alternative 4	11,5	2.63	2.10

The results from module II) of the UNITE-DSS model provide a sensitivity test based upon empirical evidence of past bias. The results show that even though the construction costs are being uplifted, the BCR values for the two alternatives 3 and 4 still indicate feasible socio-economic results. However, alternative 1 which previously returned a feasible result towards society now become infeasible with a BCR = 0.93. Such shifts in feasibility are interesting from the decision-makers' point of view and will be a matter of concern further on.

Even though this method has proven useful in a number of cases in the British Department for Transport, the derived deterministic results are still given as point estimates. The second key impact to examine, see Table 2, is the travel time savings combined with the ticket revenue. Other recent studies have concluded that risk simulation can be assessed for construction cost uncertainties in terms of an Erlang distribution (Salling, 2008; Salling and Banister, 2009; Salling and Leleur, 2009). This is, however, not given further attention in this paper.

The following sections propose a new methodological approach in order to achieve a more comprehensive assessment of the uncertainties embedded within transport infrastructure project appraisal. Specifically, modules III) and IV) of UNITE-DSS make use of a quantitative risk analysis and Monte Carlo simulation combined with reference class forecasting and scenario forecasting. The focus is on the inaccuracies in the forecasts of travel demand determining the effect of travel time savings and the ticket revenue.

Demand Forecasts (travel time savings and ticket revenue)

By far the largest contributor of direct benefits from any given transportation project are the travel time savings and the ticket revenue for user paid infrastructure. Benefits originating from this category can make up a share in the range of 70-90% of the overall benefits (Mackie et al., 2003). These most influential benefits are based on demand forecasts that can determine the travel time savings (TTS) and the ticket revenue (TR) (in the following abbreviated TTS-TR). Due to correlation between TTS and TR the UNITE-DSS model applies a single probability distribution to model TTS-TR.

A comparative study has investigated ex-ante based and ex-post based demand forecasts for rail and road infrastructure projects (Flyvbjerg et al., 2003). This study concluded that generally demand forecasts for road type projects with respect to the inaccuracy for traffic demand forecasts led to in average of 9% lower traffic than predicted. For rail type projects demand forecast in average led to 37% lower traffic than predicted. These two modes of transport have been further investigated in Salling (2008) where data fits have been performed by the use of maximum likelihood estimators. The following two figures depict respectively the fitted curve for the road type projects (Figure 3) and the rail type projects (Figure 4), in both cases suggesting the use of a Beta-PERT distribution. The Beta-PERT distribution (from here on referred to as the PERT distribution) has a background as a useful tool for modelling expert data. Thus, PERT (Program Evaluation and Review Technique) originates from 1958 where it was assigned a so-called schedule procedure (Lichtenberg, 2000).

The PERT distribution is derived from the beta distribution which mathematically is fairly simple and furthermore covers a huge variety of skewness types. When used in a Monte Carlo simulation, the PERT distribution can be used to specify risks in project and cost models especially based on the resemblance to the triangular distribution. As with any probability distribution, the usefulness of the PERT distribution is limited by the quality of the inputs: the better your expert estimates, the better results you can derive from a simulation. The mean in the PERT distribution has four times the weighting on the mode (most likely value) compared with the triangular distribution. In real-life problems we are usually capable of giving a more confident guess of the mode rather than of the extreme values, hence the PERT distribution brings a much smoother description of the tales of the impacts to be considered (Lichtenberg, 2000; Vose, 2002).

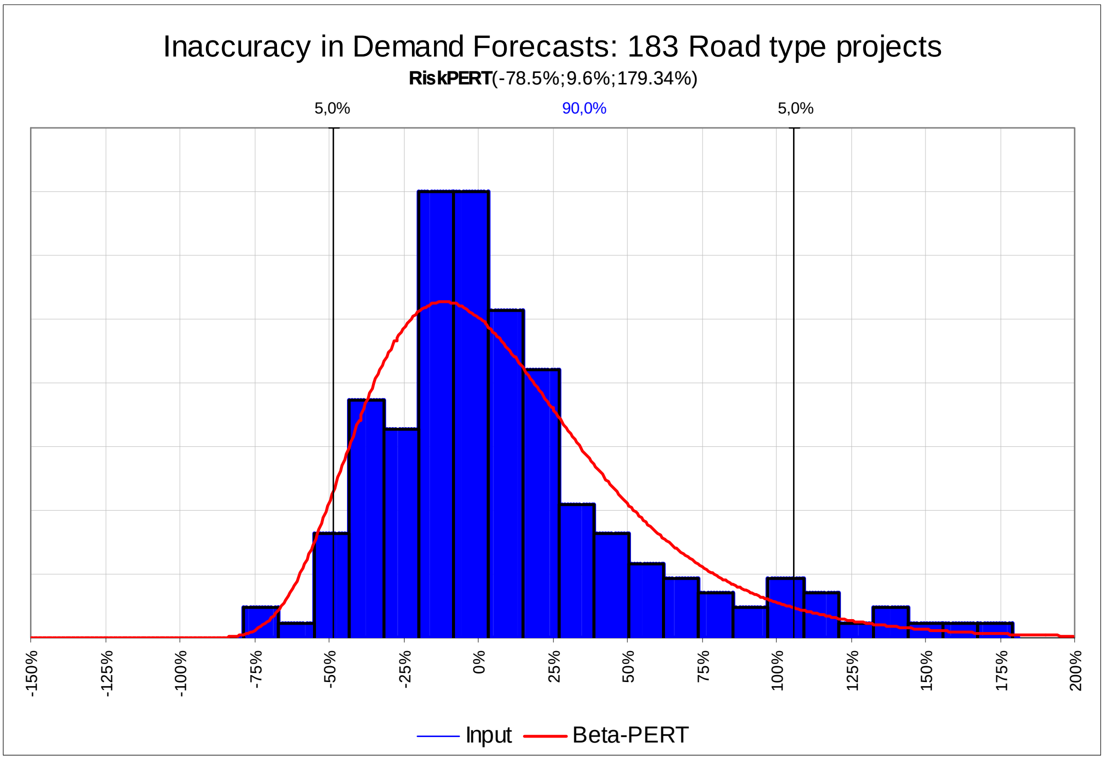

***Figure 3** – Data fit from the RCF covering 183 road type projects (Salling, 2008)*

The inaccuracy of traffic forecasts as depicted in Figure 3 and Figure 4 (below) is defined as the actual traffic minus forecasted traffic in percentage of forecasted traffic. Furthermore, the actual traffic is counted for the first year of operations (or the opening year) as estimated at the time of decision to build the project. Thus, the forecast is the estimate available to decision makers when they made the decision to build the project at question. One major issue when setting such point of reference is the disregarding of a ramp up – where most transport projects need a couple of years to reach its total effect (Flyvbjerg, 2005). Moreover, it is important to realize how traffic forecasts are made. Most forecasts rely on traffic and demand models to decide how future traffic will grow as a consequence to the new project. However, projects are not all subjected to the same scrutiny as it comes to model development and implementation. Furthermore, some studies have revealed that political accepted goals merely have been translated into forecasted traffic.

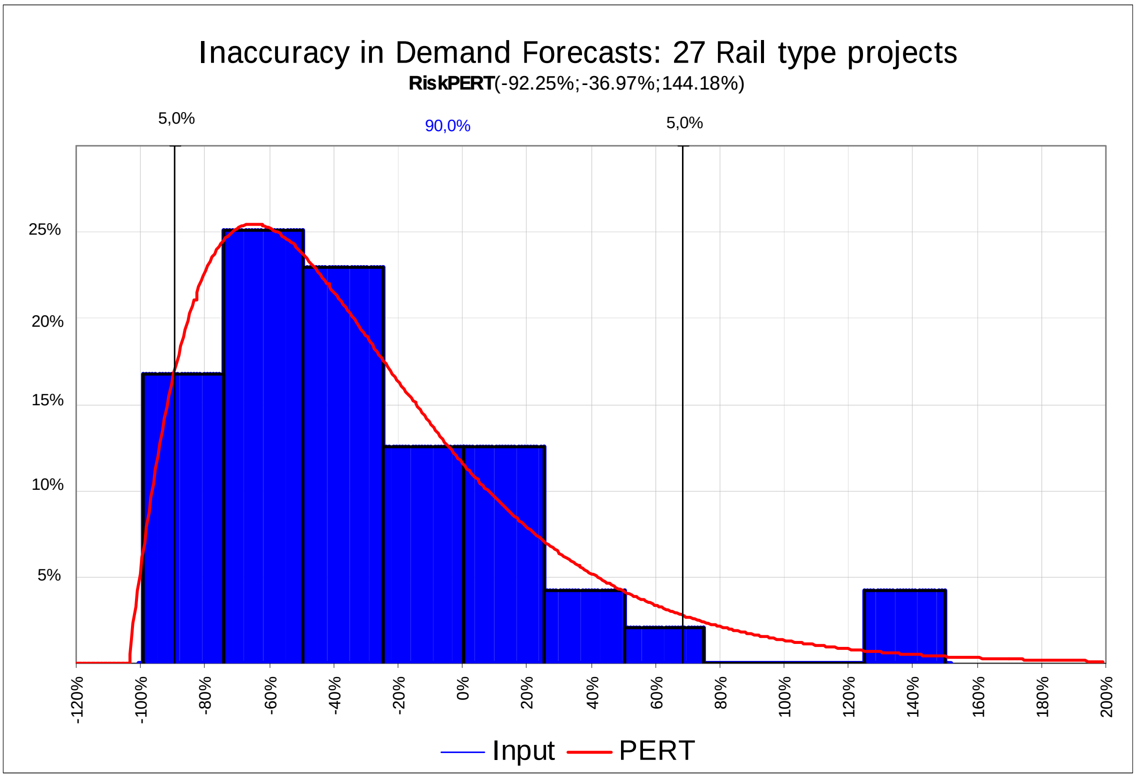

***Figure 4** – Data fit from the RCF covering 27 rail type projects (Salling, 2008)*

The two data fits (Figure 3 and 4) enter a QRA performed by the use of Monte Carlo simulation. The UNITE-DSS model run combines the uplifted construction costs shown in Table 5 with the estimated TTS-TR probability distribution functions. The interval results produced are depicted as certainty graphs i.e. accumulated descending graphs concerning the four alternatives, see Figure 5. It has been assumed that the unit prices corresponding to the travel time savings are constant only following the growth in the net price index (DMT, 2003; Salling, 2008).

Unfortunately, RCF are not available for demand forecasts of fixed link projects as a category by itself, thus, Figure 3 and 4 demand forecasts are used with a 90% confidence interval. Specifically UNITE-DSS model runs have been set up where alternative 1 and 2 (rail type projects) make use of the input parameters Beta-PERT (-90%; -37%; 68%) and alternative 4 (road type project) makes use of Beta-PERT (-49%; 10%; 106%), while alternative 3 (combined rail and road type projects) makes use of a combination between the two. The simulation is performed in @RISK version 5.0 with 2000 iterations and a Latin Hypercube sampling method (Palisade, 2007; Salling, 2008).

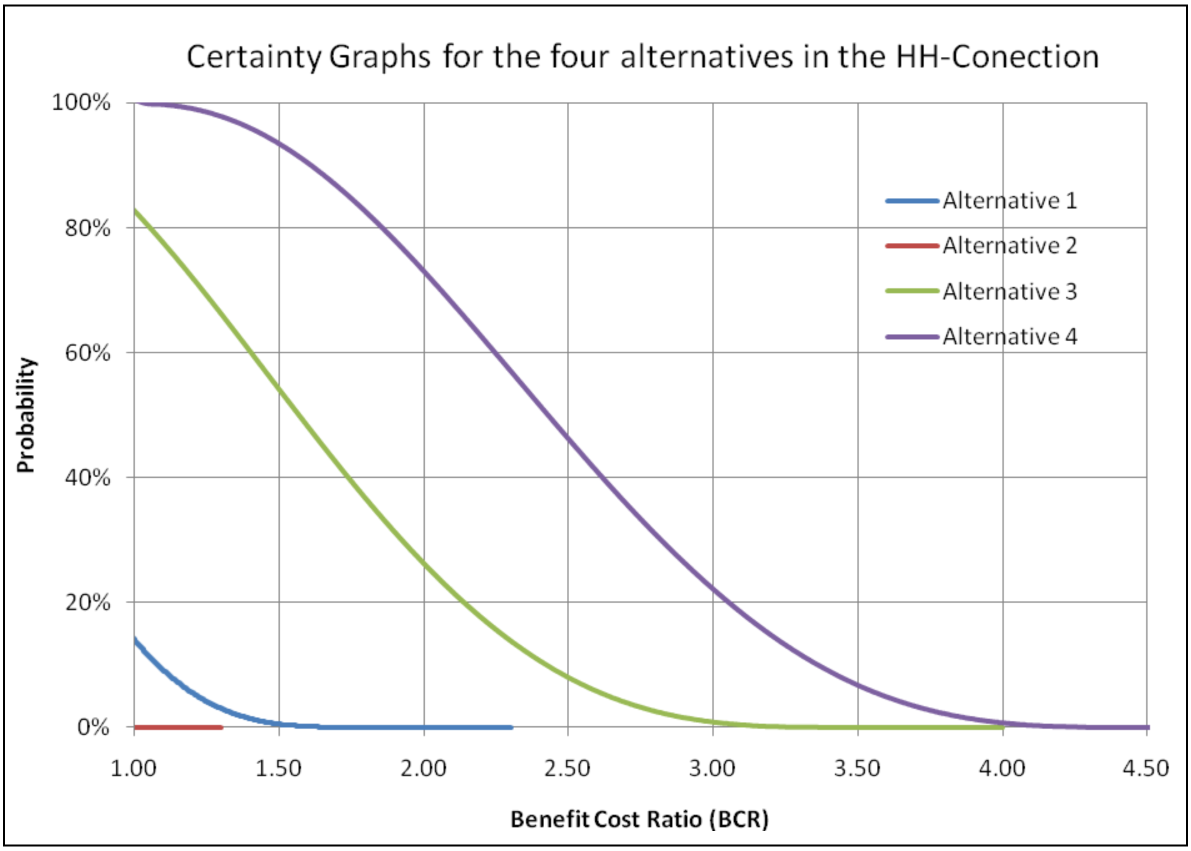

***Figure 5** – Certainty graphs for the four alternatives in the HH-Connection*

The certainty graphs depicted above show the feasibility of the different alternatives of the HH-Connection taking into account the inaccuracies in determining the demand forecasts (previously denoted feasibility risk assessment, see Salling (2008)). Please note, that alternative 2 does not become feasible in any of the Monte Carlo simulation iterations. The graphs show that the two bridge alternatives (3 and 4) perform the best, thus alternative 3 obtains a certainty value (CV) of 83% and alternative 4 obtains a CV = 100%. The certainty value or index denotes the probability of achieving a BCR ≥ 1.00. The tails of the output distributions illustrate the variance in terms of steepness, with steeper curves related to higher certainty and vice versa. Finally, Table 6 summarises the results in terms of the BCRs from module I) and II) and the certainty value of module III).

Table 6 – Results from a stochastic run in the UNITE-DSS model applying the RCF-technique with respect to inaccuracies in demand forecasts

HH-Connection (alternatives)	BCR (orig.)	BCR (Uplifts)	CV (%): (BCR = 1.00)
Alternative 1	1.15	0.93	14 %
Alternative 2	0.39	0.33	0 %
Alternative 3	2.17	1.73	83 %
Alternative 4	2.63	2.10	100 %

Table 6 shows that alternative 2 is not feasible seen from a societal point of view whereas alternative 1 seems to be feasible from a cost-benefit point of view; however, when assessing the uncertainties involved this alternative becomes “infeasible”, even though it produces feasible results in 14% of the simulation iterations. Alternative 3 and 4 perform overall the best with feasible results respectively in 83% and 100% of the simulations.

The final analysis is to perform a scenario analysis taking into account external factors in this case determined by the economic growth situation and the level of cross-border integration between Denmark and Sweden.

REFERENCE SCENARIO FORECASTING

Reference scenario forecasting is introduced as the combination of RCF and QRA brought together in a scenario-grid. Module IV) of the UNITE-DSS model provides a final calculation procedure combining all three previous modules into one overall simulation. The scenarios in this study have been set up with respect to two main types of regimes: One regime which deals with the overall economic development (both nationally as well as internationally) and one regional/cross-border regime describing the future level of integration between the countries of Denmark and Sweden. The regimes vary in a 3x3 grid as depicted in Figure 6 where the horizontal axis outlines the economic development and the vertical axis outlines the cross-border integration. Uncertainty tendencies as relating to the regimes have also been indicated in terms of arrows.

Economic development

Cross-border integration level

	High	Middle	Low
Clearly higher	Sc. 1	Sc. 4	Sc. 7
Moderately higher	Sc. 2	**Ref sc. 5**	Sc. 8
Current	Sc. 3	Sc. 6	Sc. 9

Increasing uncertainty ↑

← *Increasing uncertainty*

Figure 6 *– Scenario-grid for imagined futures for the HH-Connection project (adapted from Salling and Leleur, 2009)*

The nine scenarios that have been formulated are all expected to have different influences on the feasibility of the HH-Connection project. The reference scenario 5 forms the basis as focal scenario for the RSF and the other 8 scenarios are set by assessing the development in expected travel time related benefits. In this context the focal scenario is based on the BCR calculations produced in module III) and presented in Table 6. It has been assumed that in the actual case the construction cost effect is independent of the regimes, for which reason the Optimism Bias uplifts are considered “certain”. The TTS-TR effect, however, will no doubt change as a consequence of the economic development and level of integration. Clearly, a high economic growth together with a high level of integration will mean more people that travel both as residents but particularly business, leisure and work-related trips will increase. The opposite tendency will turn out in the case of stagnation or financial crisis. All trips will then be at a minimum and the effect will decrease due to the lower number of trips across the HH-Connection. The variation between scenarios is systematically explored and related to the scenario-grid (Figure 6).

The specific scenario input concerning the PERT distribution is assessed by combining empirical knowledge together with the triple estimation technique (Lichtenberg, 2000). Larsen and Skougaard (2010) have elaborated upon the integration between Denmark and Sweden, where the level of integration following the current speed will reach “full” integration in year 2049. Secondly, the economic growth affects the assessment study. The economic growth has been divided into a high, medium and low economic growth. It is furthermore assumed that the economic growth is correlated with the level of integration, thus, a high economic growth will lead to a high level of integration and vice versa.

Figure 7 depicts the trends associated with the benefit stemming from the TTS-TR effect associated with each alternative and scenario. The vertical axis depicts the level of integration from a starting point at index 100 (in 2024) and increasing over time associated to the horizontal axis. The opening year is 2025 and the total evaluation period has been set to 50 years. Furthermore, the three types of economic growth scenarios have varying gradients in the first 25 years after which they are set to be constant (Larsen and Skougaard, 2010).

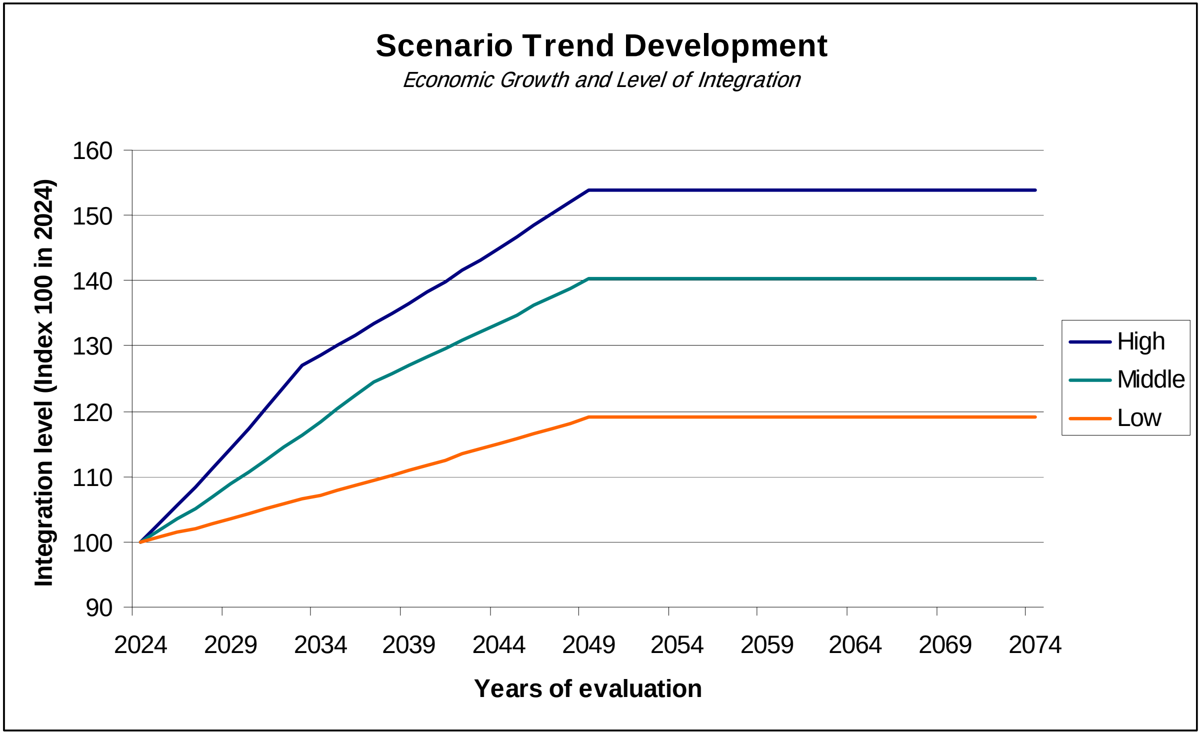

Figure 7 *– Scenario trend development (adapted from Larsen and Skougaard, 2010)*

The three trend graphs indicate possible futures with the high and low trend developments depicting upper and lower traffic forecast boundaries around a middle growth trend.

Input to PERT distribution

The main idea of RSF is based on assessing the most likely (ML), the maximum (MAX) and the minimum (MIN) values under the various scenario conditions. The scenario trend development graphs depicted in Figure 7 are converted into percentage shares and applied respectively the most likely values concerning the TTS-TR impact for scenario 1 and 9, see Table 7.

***Table 7** – Conversion of scenario trend development values*

	Index value in 2074	Most likely (ML) (%-conversion)
Scenario 1	154	SC 1 = 13.5%
Scenario 5	140	Focal SC 5 = 0
Scenario 9	119	SC 9 = -21.2%

Table 7 converts the empirical values derived from the scenario trend development graphs shown in Figure 7. By assuming the focal scenario 5 to be the reference, the best future case for the TTS-TR effect is found in scenario 1 whereas the worst future case is found in scenario 9. The remaining 6 scenarios, hence, are not further investigated due to the previous notion on correlation between economic growth and level of integration. If scenarios were formulated without such an assumption all nine scenarios must be formulated individually, see Salling and Leleur (2009).

The final step is to derive the minimum and maximum input parameters for the PERT distribution. The focal scenario 5 is based on the previous set of data fits from the RCF-technique, thus input parameters can be derived as shown in Table 8. In this context the triple values for the two final scenarios (SC1 and SC9) have been set in accordance with discussion amongst the authors and mainly for the purpose to illustrate the approach of RSF. A real-world application is currently under way in a decision conference framework where decision-makers and stakeholders will contribute to the minimum and maximum values (Goodwin and Wright, 2004 pp. 323-325; Barfod and Leleur, 2009).

***Table 8** – Focal scenario 5 TTS-TR parameters to the PERT distribution (in mio DKK)*

	MIN5	ML5	MAX5
Alternative 1	1,270 (-90%)	8,002 (-37%)	21,340 (68%)
Alternative 2	452 (-90%)	2,850 (-37%)	7,599 (68%)
Alternative 3	2,654 (-90%)	16,722 (-37%)	44,592 (68%)
	3,017 (-49%)	6,507 (10%)	12,186 (106%)
Alternative 4	9,863 (-49%)	21,274 (10%)	39,842 (106%)

Note. The MIN, ML and MAX for alternative 3 is divided to follow the data fit partly from rail and partly from road demand forecasts

These initial input parameters for the focal scenario are anchored in the following two scenarios. It is further assumed that scenario 1 is assigned a high degree of uncertainty whereas scenario 9 has a relatively low degree of uncertainty, see Figure 6. Thus, the following input parameters for the four alternatives have been derived as depicted in Table 9 and Table 10.

Table 9 *– Scenario 1 TTS-TR parameters to the PERT distribution (in mio DKK)*

	MIN1	ML1	MAX1
Alternative 1	1,270 (-90%)	14,421 (+13.53%)	27,691 (+118%)
Alternative 2	452 (-90%)	5,135 (+13.53%)	9,861 (+118%)
Alternative 3	1,898 (-90%)	18,985 (+13.53%)	41,386 (+118%)
	3,767 (-49%)	7,387 (+13.53%)	18,912 (+156%)
Alternative 4	9,863 (-49%)	21,957 (+13.53%)	49,512 (+156%)

Table 10 *– Scenario 9 TTS-TR parameters to the PERT distribution (in mio DKK)*

	MIN9	ML9	MAX9
Alternative 1	-5,081 ≈ 0 (-140%)	10,004 (-21.24%)	14,989 (+18%)
Alternative 2	-1,809 ≈ 0 (-140%)	3,563 (-21.24%)	5,338 (+18%)
Alternative 3	-5,268 ≈ 0 (-140%)	13,170 (-21.24%)	15,541 (+18%)
	51 (-99%)	5,125 (-21.24%)	8,507 (+66%)
Alternative 4	193 (-99%)	15,232 (-21.24%)	32,105 (+66%)

Please note, that alternatives 1, 2 and 3 in scenario 9 for the road TTS-TR comprise negative values. Evidently, this is not valid since a transport infrastructure project with negative user benefits would be rejected in the pre-analysis of the project. Thus, the lower boundary of the triple estimate has been rounded to 0 (Table 10).

Results from the reference scenario forecasting

Results from the final RSF risk simulation run in the UNITE-DSS model is shown in Table 11.

Table 11 *– Certainty value results from the reference scenario forecasting*

HH-Connection (alternatives)	CV (%) Scenario 1	CV (%) Scenario 5	CV (%) Scenario 9
Alternative 1	57 %	14 %	5 %
Alternative 2	0 %	0 %	0 %
Alternative 3	93 %	83 %	66 %
Alternative 4	100 %	100 %	80 %

The values indicate the certainty (probability) of achieving the threshold value (BCR = 1.00) denoted on the y-axis of the certainty graph, see Figure 8. From Table 11 it is clear that alternative 4 performs overall the best, where, the most pessimistic scenario still returns an 80%-feasibility of the project. Moreover, alternative 2 should be rejected since none of the scenarios returns a feasible result. The certainty graphs from module IV) of the UNITE-DSS model are shown in Figure 8.

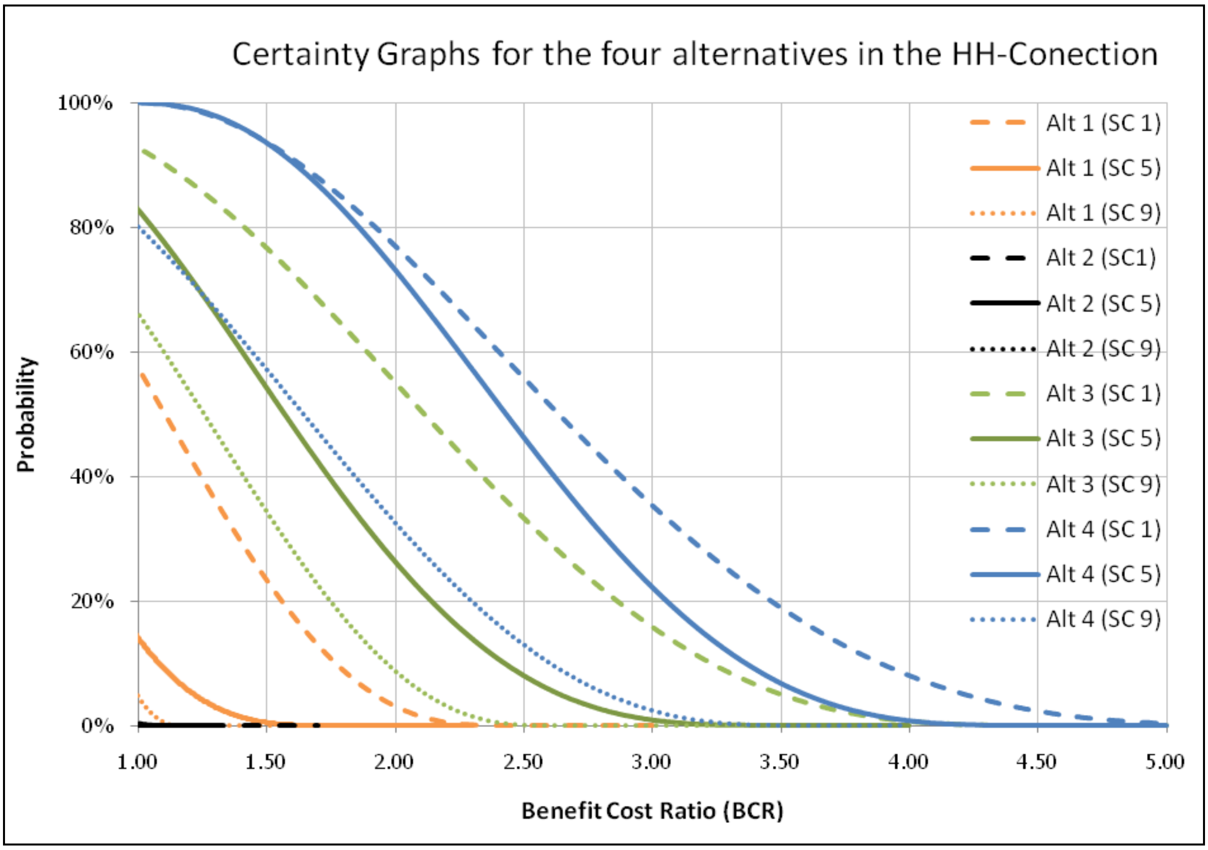

Figure 8 *– Certainty graphs from the reference scenario forecasting run*

Characteristically, the certainty graphs are downward sloping illustrating the uncertainty of the alternative within the scenario. The risk aversion is shown on the y-axis where the level of certainty is displayed. Thus, decision-makers with no risk aversion would only allow alternative 4 in scenario 1 and 5 to be selected. However, lesser risk aversive decision-makers would allow for 70% or 60% certainty of feasibility. If this were the case, alternative 3 in all scenarios would also be of relevance.

From the analyses carried out in this paper for the four HH-Connection alternatives alternative 4 performs the best. Whether this project alternative should call for implementation, however, is a different issue. Especially, the main difference between the two alternatives 3 and 4 concerning travel modes must be considered before the final choice. Furthermore, the RSF approach considered in this paper only relies upon the cost-benefit approach comprising monetary quantifiable impacts. However, non-quantifiable impacts such as landscape, ecology, regional economic development, transport network and accessibility, etc., have not been treated. These types of impacts calls for a multi-criteria analysis where qualitative measures can be applied, see e.g. Leleur et al. (2010).

CONCLUSION AND PERSPECTIVE

The paper has presented a new methodological approach, reference scenario forecasting, to explore embedded uncertainties in transport project assessment. Reference scenario forecasting (RSF) combines reference class forecasting (RCF) and quantitative risk analysis (QRA) with a scenario-grid, where the different scenarios are specified in an operational way by using triple estimates. A major strength of the RSF is that overall feasibility risk assessment can be carried out by using historical experience stemming from RCF and by linking this to formulated scenarios of relevance for a particular case study.

The RSF approach has been illustrated on a case example concerning the construction of a new fixed link, the HH-Connection, between Denmark and Sweden. It has been demonstrated that RSF has a capability of providing informed decision support for a complex problem in a straightforward way based upon risk simulation and scenario forecasting. The introduction of a set of triple estimates assigned the travel time savings effect comprises assessment information based upon judging the embedded risks of the project. Hereby, decision-makers are able to view and appraise their preferences towards an alternative in terms of feasibility risk assessment. A future task is to clarify and validate the inputs to the probability distribution functions drawing upon stakeholder and decision-maker involvement. One issue to further investigate would be to apply a decision conference for this purpose.

An important aspect in RSF is to set and validate input parameters. Hence, empirical data enter the assessment in terms of RCF and Optimism Bias uplifts. However, care must be taken in applying such data as they are based upon historical e.g. past trends and state of the market. An important task is to supplement the set of reference classes with plausible trend scenarios that can represent new possible developments.

The RSF approach has been implemented in a decision support software model, UNITE-DSS. The approach relies on clearly defined and debated scenarios where a future task will be to develop a set of guidelines, i.e. short-list containing widely-embracing scenarios such as oil prices, evolution of the energy market and environmental initiatives could be of interest. This software carries the assessment study forward in different modules (I-IV) all anchored in monetary quantifiable measures. These modules rely on well-explored methodologies: cost-benefit analysis, Monte Carlo simulation and RCF. Future tasks are to develop the UNITE-DSS model to be informed by decision conferences. This linkage of modeling and decision-makers is seen as highly important to explore and assess the full potential of RSF. The issues of risk and uncertainty should be central in all types of project analysis as substantial sums of capital are transferred to transport infrastructure projects. Better and more comprehensive approaches towards transport assessment for decision making are therefore essential.

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