HOW TO REFLECT THE ISSUE OF RISK IN TRANSPORT INFRASTRUCTURE APPRAISAL: SYNTHESIS OF METHODS AND BEST PRACTICE

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ABSTRACT

Planning, constructing, financing and operating transport infrastructure involves a wide range of different risks. This poses a challenge for the appraisal of transport infrastructure projects. The current paper addresses this challenge by giving an overview on applied methodologies reflecting the issue of risk by transport infrastructure evaluation concepts. The paper starts with defining 'risk' and substantiating the pattern of 'risk' in transport infrastructure planning. Subsequently, five basic methodologies to incorporate the issue of risk in transport project appraisal are presented: sensitivity analysis, scenario analysis, Monte Carlo Simulation, Quantified Optimism Bias and qualitative approaches. For each methodology, real-world applications of infrastructure appraisal in individual countries, regions or supranational organizations are presented. Finally, the applied methodologies are illustrated in a synoptic overview. Based on the findings of applied practice, recommendations are elaborated.

Keywords: transport infrastructure, risk, assessment, sensitivity analysis, scenario analysis, Monte Carlo Simulation, Optimism Bias, project appraisal

INTRODUCTION

Transport infrastructure projects are exposed to a multitude of risks due to their time consuming planning and implementation processes, complex interfaces between the heterogeneous actors involved, as well as the differences between the applied economical and technical methodologies (UK DfT 2011). Such risks often manifest themselves in considerable cost overruns (e.g. Flyvbjerg et al. 2002, 2004; Flyvbjerg 2008; MacDonald 2002) and inaccurate demand expectations (e.g. Flyvbjerg et al. 2005).

Thus, risks associated with implementing transport infrastructure projects may have severe impacts on public and private budgets. Therefore, it is crucial to anticipate possible risks within the evaluation process, whose result determines whether or not an individual project will actually be realized. Several authors have developed approaches how to better consider the issue of risk in the evaluation process of infrastructure projects (e.g. Joumard and Nicolas 2007; Ye and Tiong 2000; Salling 2008; Salling and Banister 2009). However,

realizing such approaches in decision-making processes in a specific country or a supra-national community seems to be more challenging. The current paper, therefore, aims at providing an overview on applied methodologies reflecting the issue of risk by transport infrastructure evaluation concepts. After a comprehensive synthesis of the depicted methods and the lessons learned, recommendations are drawn. The focus of this paper is how risk is dealt with at the stage of project appraisal. Managing risks after having decided to implement a project is crucial – for instance during the construction (Sander 2012; Ashley et al. 2006), and operating stage (Alfen et al. 2011), as well as governance aspect in general (e.g. Sanderson 2012) – but beyond the scope of the current paper.
The paper is organized as follows: The paper starts with defining 'risk' and substantiating the pattern of 'risk' in transport infrastructure planning. Subsequently, five basic methodologies to incorporate the assessment of risks into the transport project appraisal are presented. For each methodology, real-world applications of infrastructure appraisal in individual countries, regions or supranational organizations are described. Finally, the applied methodologies are illustrated in a synoptic overview. Based on the findings of applied practice, recommendations are elaborated.

METHODOLOGY

This chapter contains an overview on the state of the art on how the occurrence of risk is taken into account when assessing projects.
The chapter starts with a brief summary of risks which are associated with appraisal of transport infrastructure projects. Subsequently, methods to address risk in project appraisal are presented: sensitivity analysis, scenario analysis, Monte Carlo Simulation, Quantified Optimism Bias and qualitative approaches. These method descriptions are complemented with real-world application examples from supranational, national and regional entities: the European Union (EU), Australia, Canada, France, Denmark, Germany, Spain (Junta of Andalusia), Switzerland and the US state of Washington.
Main attention is given to procedures for incorporating those risks, which influence projects' benefits and costs. Environmental Risk Assessment is not dealt with in this paper.

Risks in Appraisal of Transport Infrastructure Projects

Infrastructure projects pass through several stages including planning, appraisal, formal approval, procurement, construction, operation and maintenance. During each of the stages, risks occur that influence the overall success of the project. The key challenge during the appraisal stage is to anticipate possible risks that are inherent to subsequent stages of project implementation.
The occurrence of risks associated with (large) infrastructure projects has been subject to several analyses (e.g. Flyvbjerg et al. 2003; Lam 1999). The majority of risks pertaining to project appraisal is associated with the following elements:

- investment costs
- forecasts of socio-economic benefits
- length of construction period

The latter factor has an impact on investment costs. Therefore, for the purposes of project appraisal, risks need to address

(1) investment costs
(2) forecasts of socio-economic benefits.

Investment Costs

The pattern of cost overruns of transport infrastructure projects has been extensively examined, for example, by Back et al. (2000), Flyvbjerg (2008), and Cantarelli et al. (2010). Empirical data clearly reveals that investment costs systematically tend to be under-estimated. When analysing 258 transport infrastructure projects worldwide Flyvbjerg (2008) concluded that "forecasted costs are biased and the bias is caused by systematic underestimation" (dto.: 127). Figure 1 visualizes the percentage escalation of cost estimates of infrastructure projects.

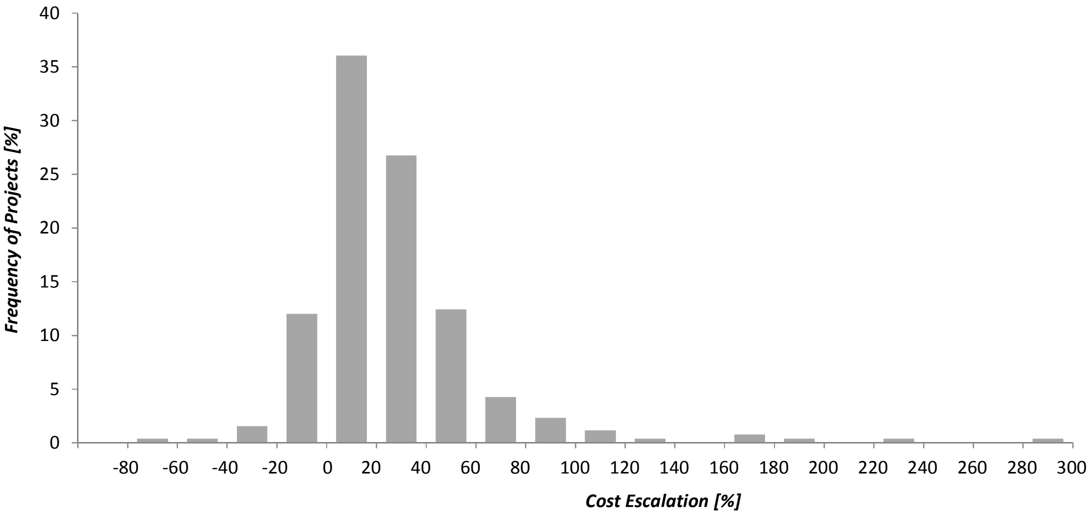

Figure 1: Inaccuracy of cost estimates (based on Flyvbjerg et al. 2002)

Although research related to empirical data of an individual country may reveal different results, like the analyses by Cantarelli et al. (2012) for the Netherlands, rail infrastructure projects generally tend to show the highest percentage of cost overruns, followed by fixed links, while real costs of road projects tend to be closer to forecasted costs.

Flyvbjerg et al. (2003) derived four main causes of cost overruns. Based on these categories, Cantarelli et al. (2010) further elaborates on causes of cost overruns based on extensive literature research. The main causes identified for cost overruns are as follows (dto.):

- technical reasons, e.g. poor project design or increase in prices
- economic reasons, e.g. lack of incentives to provide accurate forecasts of costs
- psychological reasons, e.g. cognitive bias which results in optimistic cost forecasts
- political reasons, e.g. deliberate underestimation of costs to increase the chance of a project to become approved

Forecasts of Socio-Economic Benefits

The forecasting of socio-economic benefits embraces two aspects. The first being forecasts on quantities such as estimated demand, time savings or change in air emissions. The second concerns the (monetary) valuation of quantities, such as assumptions on value of time (VOT) or prices of external impacts. Both aspects may lead to unrealistic forecasts of socio-economic benefits. Transport demand forecasts are an important basis for quantifying socio-economic benefits. Several authors have analysed the scope of bias in transport demand forecasts (e.g. Bain 2009; Flyvbjerg 2008; Flyvbjerg et al. 2006). When evaluating forecasts of 210 infrastructure projects, Flyvbjerg et al. (2005) discovered that demand forecasts are overestimated for more than 40% of the analysed infrastructure projects by 20% or more, as plotted in Figure 2.

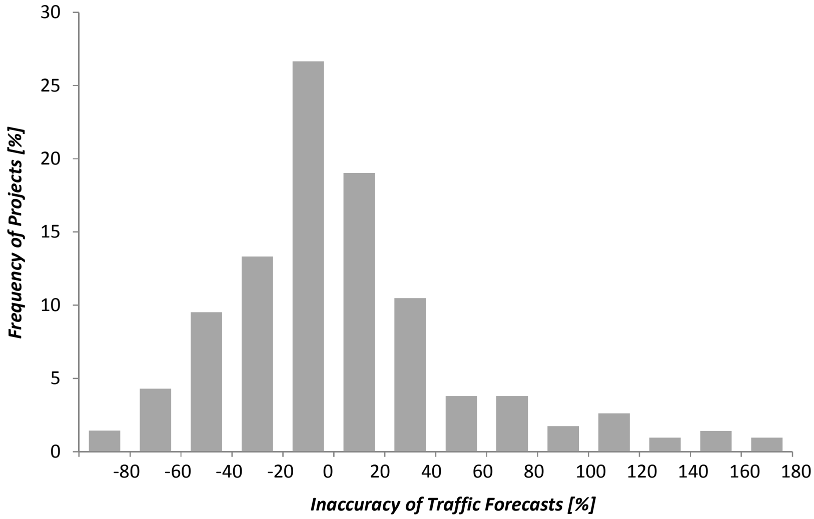

Figure 2: Inaccuracy of traffic forecasts in transportation infrastructure projects (based on Flyvbjerg et al. 2005)

Flyvbjerg (2008) concludes that rail passenger demand forecasts are “consistently and significantly inflated”, while the problem of inaccurate forecasts related to road infrastructure projects is “less severe and less one-sided”. Mackie and Preston (1998) gave an overview of the reasons for inaccuracies that range from the issue that not even the present transport situation is accurately known to model errors or incorrect definitions of reference and do-something cases.

Sensitivity Analysis

General Definition

The sensitivity analysis examines the degree to which the outcomes of a calculation are affected by changes or disturbances. Within the assessment of infrastructure projects, the sensitivity analysis evaluates „how changes in particular assumptions would affect NPVs, total costs or other project outcomes” (OECD 2002).
Sensitivity analyses can also be applied to calculate switching values and identify critical variables: switching values highlight the change in a variable required for the project decision to switch from acceptance to rejection. Critical variables have an important impact on the evaluation results such as the Net Present Value (NPV).

Application Examples

In **Australia**, the sensitivity analysis is a key element in the risk assessment of demand modelling and Cost Benefit Analysis (CBA) (Infrastructure Australia 2010a, 2012).
Variables addressed in the sensitivity analysis are as follows: Capital costs, construction time (and resulting opening date), operating costs (including maintenance), benefits, oil prices, carbon prices, demographic developments, GDP growth rates, demand modeling results and discount rate. Furthermore, it is recommended to analyze the impacts of varied annualization factors and VOT values.

In the case of **Canada**, sensitivity analysis is the first step of incorporating risk in the evaluation process. The variables considered within the sensitivity analysis are as follows: transport demand, prices, technology, logistics, technical performance, cost estimates, standard values (e.g. value of fatalities, injuries), timing, discount rate, conditions for the accrual of benefits and accrual of full benefits (Transport Canada 1994).
The sensitivity analysis is applied to determine whether the selected project alternative is optimal. If the sensitivity analysis reveals circumstances under which “different options would become cost-beneficial, a more detailed assessment is needed of the risk that the best option is being selected” (Transport Canada 1994). A more detailed assessment of this ‘option risk’ embraces the “determination of the circumstances that would have to prevail for particular options to be the most attractive and the likelihood of these circumstances being realized” (dto.). Furthermore, switching values are calculated to determine variable or parameter values that “make a particular option the most cost-beneficial” (dto.).

In **Denmark,** the result of the CBA consists of deterministic single values, which are enriched by outcomes of a sensitivity analysis (DMT 2003).
First, significant uncertainties and key assumptions are identified that may influence the assessment result. Subsequently, variables that substantially contribute to the uncertainty associated with project performance are subject to sensitivity analyses (dto.): Fixed costs, traffic volume, VOT, and discount rate.
Switching values are calculated for fixed costs, traffic volume and VOT with respect to the socio-economic assessment results and the ranking between project alternatives.

A sensitivity analysis is required for the appraisal of projects supported by the **EU** (funded or co-funded by the Structural Fund-ERDF, Cohesion Fund or Instrument for Structural Policies in Pre-Accession Countries) (EC 2008).
The sensitivity analysis is comprised of six steps First, the variables subject to sensitivity analysis are identified. An indication for variable categories to be considered is provided in Table 1. Second, before calculating elasticity values, a rough qualitative analysis is recommended in order to isolate variables with high elasticity. Subsequently, several calculations of the performance measure (e.g. NPV) are conducted for each variable, as it cannot be assumed that all variables have a linear elasticity. Fourth, criteria for the identification of critical variables are determined. Such criteria are elaborated on a case-by-case basis. During the fifth step, the sensitivities of all selected variables are calculated, and subsequently, critical variables are identified by applying the defined criteria. Finally, switching values are derived for the critical variables.

Table 1: Variable categories to be considered when identifying critical variables and a selection of variable examples (EC 2008)

Categories	Examples of variables
Price dynamics	Rate of inflation, growth rate of real salaries, energy prices, changes in prices of goods and services
Demand data	Population, demographic growth rate, specific consumption, demand formation, volume of traffic, size of the area to be irrigated
Investment costs	Duration of the building site (delays in realisation), hourly labor cost, cost of land, cost of transport, distance from the quarry
Operating costs	Prices of the goods and services used, hourly cost of personnel, price of electricity, gas, and other fuels
Quantitative variables for the operating costs	Specific consumption of energy and other goods and services, number of people employed
Prices of revenues	Tariffs, sale prices of products, prices of semi-finished goods
Quantitative variables for the revenues	Volume of services provided, productivity, number of users, percentage of penetration of the area served, market penetration
Accounting prices for costs and benefits	Coefficients for converting market prices, value of time, cost of hospitalisation, cost of deaths avoided, shadow prices of goods and services, valorisation of externalities
Quantitative variables for costs and benefits	Sick rate avoided, size of area used, added value per hectare irrigated

In the case of **France**, a sensitivity analysis is mandatory for major transport infrastructure projects (METL 2004), and rural road projects (METL 1998).
Within the evaluation guideline for major transport infrastructure projects, those variables are specified, which, as part of the socio-economic impact assessment, are to be analysed by sensitivity tests. Variables to be varied are: GDP growth, investment and operating costs, traffic volume, cost of energy and relative prices of competing transportation modes, price of human life, costs of noise and pollution, as well as expected public subsidies.
For rural road projects, values for high- and low-level traffic demand are applied and combined with three assumptions on investment costs (reference case, high, low). Switching values for both transport demand and investment costs are derived. In addition to the combined variations of traffic demand and investment costs, monetary values for externalities are suggested to be subject to sensitivity analyses.

In **Switzerland,** sensitivity analysis is carried out to ensure robust assessment results (DETEC 2005). With regard to the variables subject to analysis, a distinction is made between those being considered in the underlying transport model and those not being incorporated.
Figure 3 shows five variables subject to analysis by sensitivity analysis: VOT, real growth of wages and traffic demand are varied at the stage of transport modelling, while the discount rate and the construction costs are varied within the CBA stage. For small projects, the sensitivity analysis is only carried out within the CBA stage, without performing additional model runs.
Apart from these compulsive sensitivity tests, the evaluation methodology recommends analyzing all other project specific variables that have a high impact on the overall assessment result and whose performance is subject to uncertainty.

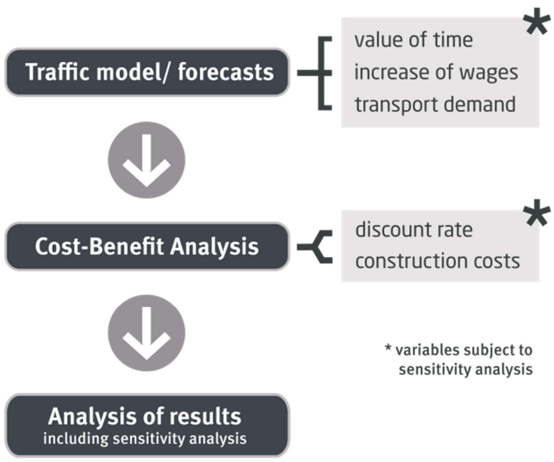

Figure 3: Schematic approach of application of sensitivity analysis in case of Switzerland

In **Spain (Junta of Andalusia)**, the following variables are subject to sensitivity analysis for the evaluation of road infrastructure projects (Junta of Andalusia 2010): investment cost (±10%), capital target rate of potential concessionaire (±1%, 10% being the reference case), operating and maintenance costs (±10%), discount rate (±1%, considering possibly varying capital costs), lifespan (±5 years, 30 years being the reference case), and correction value (for the case that the infrastructure is temporarily unavailable or only partly available).

In the **United Kingdom (UK),** sensitivity analyses are used at several steps during the assessment process.
First of all, a sensitivity analysis of inputs in the forecasting process is advised (UK DfT 2011). Apart from a base case, either two alternative scenarios or two sensitivity analyses form the basis of a full appraisal. The scenarios are based on a systematic analysis of drivers such as background trends (e.g. GDP growth or fuel costs), political or commercial uncertainty (other, interdependent, transport projects might be approved or not), along with regional, economic or planning uncertainty and other factors (e.g. a policy initiative that influences the travellers' mode choice). In case a common VOT is applied to all travellers "sensitivity tests should be carried out, using values disaggregated by modal group" (UK DfT 2012b).
Secondly, a sensitivity analysis of the impact of the project on local transport providers is carried out. Whereas the most likely response to the initiative should be reflected within a central case, all other possible responses should be assessed within a sensitivity analysis (dto.). Three or four likely operator responses are to be considered with respect to fares, route or frequency changes.
Thirdly, the optimism bias uplift on construction costs undergoes a sensitivity analysis and is carried out at every planning stage of the project (UK DfT 2012a).
Fourthly, risks associated with patronage or benefits are recommended to be dealt with by sensitivity or scenario testing on the basis of the reference case. Moreover, possible deviations from forecasted operating costs are evaluated within a sensitivity.
Fifthly, within the 'Quantified Risk Assessment', the impacts of identified risks are identified by either applying a sensitivity analysis or using outcomes from similar schemes (dto.).

Scenario Analysis

General Definition

In contrast to a sensitivity analysis, a scenario analysis implies the variation of several variables simultaneously. Scenario analysis – whose origin of the methodology can be found in the field of military strategies (see e.g. Kahn 1960) – allows the consideration of possible exogenous trends or events that influence multiple variables at the same time. A scenario is not a forecast, but rather an internally consistent description of a possible future economic and political environment" (OECD 2002).
'Interval analysis' constitutes a particular type of scenario analysis, developing worst and best case scenarios by applying the highest or lowest possible value of each variable.

Application Examples

Investment and policy decisions in **Australia** are required to be based on several possible future scenarios at three evaluation steps (Infrastructure Australia 2012):
Firstly, a scenario analysis is required in the assessment process to show that the actual infrastructure deficits faced are "likely to be enduring and significant under a range of scenarios". The scenario analysis needs to identify whether infrastructure deficits – e.g. regarding accessibility, availability, prices/cost, capacity, emissions or safety – are enduring or temporary (Infrastructure Australia 2010b).
Secondly, several possible options are elaborated to overcome the identified deficits. As alternatives to capital investments, possible options "are expected to cover a range of alternative solutions" such as regulatory, governance or better use reforms. Identified options are subsequently assessed to elaborate whether they are still effective under a range of scenarios. Consequently in each option selection stage (long list, interim list, short list), it is recommended to incorporate different scenarios (Infrastructure Australia 2010b, 2012).
Thirdly, the preferred option is analysed within three or four scenarios (including worst case scenarios with a 30% increase of costs and a 30% decrease of benefits) (Infrastructure Australia 2010a, 2012).
The scenarios are recommended to be based on various drivers of change (and interactions between them) and their impact on the infrastructure network, respectively. The following drivers of change are suggested to be considered, as they are likely to have the greatest significance for Australia's infrastructure systems: Socio-demographic change, economic change, energy prices, impacts on climate change, technological change, and governance change.
Infrastructure Australia (2012) advises to present the scenario analysis results quantitatively. However, some qualitative descriptions are advised, particularly if information is not quantifiable due to lack of data.

In **Canada**, a scenario analysis is recommended in cases where a simultaneous variation of several variables of the sensitivity analysis is regarded 'appropriate' (Transport Canada 1994). The variables of a scenario are determined by the variables of the sensitivity analysis.

The **EU** requires project assessments to be conducted under application of scenario analysis in two stages of the appraisal process. (EC 2008).
Firstly, within the feasibility and option selection stage, the best options are selected. The feasibility analysis ascertains that the project is needed and implementable, which is achieved by comparing alternative solutions within different scenarios: A 'business as usual' scenario (no investment) is opposed to the project realization scenario ('do-something'). In some cases, a 'do minimum project' (e.g. partial modernization of an existing infrastructure) or a 'do-something-else' option should additionally be considered. The latter does not necessarily include investments, but also aspects such as regulation (e.g. "pricing changes, alternative infrastructure interventions"). Based on the selected scenarios, it is recommended to apply an optimistic and a pessimistic traffic volume scenario on the alternatives, in case future demand trends are subject to uncertainty.
Secondly, within the assessment stage, all valid potential impacts are computed for the best and worst case scenarios.

In **France**, scenario analysis is applied for major transport infrastructure projects (METL 2004) and rural road projects (METL 1998).
For major transport infrastructure projects, variables to be varied are specified as follows: GDP growth, investment and operating costs, traffic volume, cost of energy and relative prices of competing transportation modes, price of human life, costs of noise and pollution, and expected public subsidies. It is compulsory to determine most probable and plausible values of these variables, in addition to a best and a worst case. Decision criteria of the socio-economic evaluation are subsequently calculated by combining these values to a most probable scenario, and to best- and worst-case scenarios. Subsequently, alternatives to the project implementation are elaborated and assessed. This could include the modification of the road toll pricing system or adjusting the regulations of other modes of transport (METL 2004).
With respect to different traffic development scenarios, the forecasts of different institutions are considered for rural road projects (METL 1998). Setra (Service d'études sure les transports, les routes et leurs aménagements) (2008) provides such forecasts under application of software to support scenario design when analyzing and forecasting infrastructure projects on the French road network.

In **Germany**, three general scenarios are elaborated as a basis for transport demand forecasts. One of these scenarios, the so-called 'integration scenario', is used for the assessment of all infrastructure projects (BMVBW 2005). Consequently, there is no scenario-wise project appraisal.

For the evaluation of road infrastructure projects in **Switzerland** a check is carried out for whether the probability of a worst-case scenario can be determined. If it is possible to derive a probability for the worst-case scenario, the project is evaluated on the basis of the worst- and best-case combinations of variables (see variable recommendation in sensitivity analysis) (DETEC 2005). As much as feasible, the evaluation of infrastructure projects embraces the consideration of alternative measures and variants of the project.

In the **UK**, scenario analysis is applied in three stages of project appraisal.
Firstly, the Do-Minimum and Do-Something project cases are evaluated on the basis of a reference (most likely), a pessimistic and an optimistic scenario. Do-Something options are divided into a 'preferred' option – the construction of new infrastructure – and 'next best' and 'lower cost' options. The scenarios applied to those options cover uncertainties with respect to technical, economic, political and local developments. All finalized scenarios are agreed with the Department for Transport, and each scenario serves as the basis for the assessment of the infrastructure project (UK DfT 2004).
Secondly, risks associated with patronage or benefits are dealt with by sensitivity tests or scenario analyses on the basis of the reference case (UK DfT 2012a).
Thirdly, in order to deal with uncertainty of evaluation results due to different assumptions on future developments, the different views may be described in a scenario, in which the effect of assumptions on evaluation results are described (UK DfT 2011). Scenarios are used to capture different possible future conditions with respect to planning and land-use issues, as well as the timing and delivery of other transport schemes (infrastructure conditions, other modes, operating concepts etc.). Apart from a reference case, either two alternative scenarios or two sensitivity analyses are required.
The assessment of uncertainty with regard to future availability of transport schemes is captured by an 'uncertainty log'. The likelihood of occurrence is categorized 'near certain', 'more than likely', 'reasonably foreseeable' and 'hypothetical'.
Table 2 illustrates the probability categorization of other transport schemes in relation to their implementation status. When creating the reference scenario, only inputs categorized as 'near certain' and 'more than likely' are included, whereas 'reasonably foreseeable' and 'hypothetical' are excluded. Within the alternative scenarios, more insecure inputs are considered as well.

Table 2: Input categories as basis for scenario development (UK DfT 2011).

Delivery of other transport schemes	Implementation status
Near certain: The outcome will happen, or there is a high probability that it will happen.	▪ Intent announced by proponent to regulatory agencies ▪ Approved development proposals ▪ Projects under construction
More than likely: The outcome is likely to happen, but there is some uncertainty.	▪ Submission of planning or consent application imminent ▪ Development application within the consent process
Reasonably foreseeable: The outcome may happen, but there is significant uncertainty.	▪ Identified within a development plan ▪ Not directly associated with the transport strategy/scheme, but may occur if the strategy/scheme is implemented ▪ Development conditional upon the transport strategy/scheme proceeding ▪ Committed policy goal, subject to tests (e.g. of deliverability) whose outcomes are subject to significant uncertainty
Hypothetical: There is considerable uncertainty whether the outcome will ever happen.	▪ Conjecture based upon currently available information ▪ Discussed on a conceptual basis ▪ One of a number of possible inputs in an initial consultation process ▪ Policy aspiration

The **US state of Washington** requires the application of a risk management process for evaluating capital transportation projects (WSDOT 2008). For projects with a budget of over 25 mill. USD workshops are held: 'Cost Risk Assessment workshop' (project costs 25-100 mill. USD), and a 'Cost Estimate Validation Process Workshop' (project costs > 100 mill. USD). Scenario analysis is used as a possible option for 'conflict resolution': If the discussions during these workshops do not result to a consensus view on probabilities of occurrence and expected impacts of risks, scenario analysis may be applied. Thus, if it is not possible "to resolve the difference by capturing it as a range" or distribution, it "may be appropriate to evaluate additional scenarios that address the different opinions being offered" (WSDOT 2010). The guidelines emphasize, however, the need to restrict the number of different scenarios: "Having too many scenarios can add cost and complexity […] and may not be necessary or helpful to the overall evaluation of the project" (dto.).

Monte Carlo Simulation

General Definition

Monte Carlo Simulation is a "computer-based technique of analysis that accepts information about the … input parameters in the form of ranges of values and distributions of possible parameters that are subject to uncertainty", whose results "are expressed in terms of the expected outcome and the probabilities of key outcomes occurring" (The Treasury Board of Canada Secretariat 2007).
The technique is particularly useful for the aggregation of numerous risks with dependencies. Each uncertain variable is assigned to an assumed probability distribution. As the chosen probability distributions significantly influence the result of the simulation, they need to be elaborated thoroughly (Frey and Niessen 2001).
A Monte Carlo Simulation consists of many simulation runs. During each run, a value for each variable is selected from the determined distribution using a random generator. The "law of large numbers" – the mathematical basis of the method – leads to convergence towards the real value of the target variable with an increasing number of simulation runs (Frey and Niessen 2001). By taking a very large sample from each distribution, the sampling distribution approximates the theoretical distribution. The result of the Monte Carlo Simulation is a probability distribution of the target variable. This distribution allows the application of confidence intervals on the target variable.
Threshold values are a necessary prerequisite to calculate a "probability that the output will exceed a specific threshold or performance measure target value" (Loucks et al. 2005). This is particularly beneficial if funding of a project depends on a certain minimum NPV or other decision criteria.

Application Examples

In **Australia**, 'construction risks' and 'other risks' need to undergo probabilistic risk assessment. In order to capture 'construction risks', a risk-based cost estimate is elaborated following a probabilistic modelling approach. Examples of risks considered are risks due to the project's location and geology, and risks to the wider network. Moreover, 'associated works' are analysed with respect to their scale and costs, as well as to their funding (Infrastructure Australia 2010a).
'Other risks' subsume impacts of social, political and any other significant risks on the project's cost estimate. They are recommended to be considered by a risk-based project estimate, preferably using Monte Carlo Simulation (dto.).

In the case of **Canada**, a probabilistic analysis of the benefit-cost investment criteria is suggested. “The greater the uncertainty associated with a project, or the more complex a project, the more cost effective the use of a quantified approach becomes to deal with uncertainties” (Transport Canada 1994).
In order to determine a probability distribution for the NPV, assumptions are made regarding the probability distributions for key variables. The guideline does not further specify key variables, however the variables provided for the sensitivity analysis could be interpreted as an indication.

In **Denmark**, a Monte Carlo Simulation may be conducted, alternatively to the sensitivity analysis (DMT 2003). No specific requirements are stated with respect to the uncertainty factors to be considered within the Monte Carlo Simulation, which implies that Monte Carlo Simulation may be applied for the estimation of both costs and benefits.

For the **EU,** appraisals of projects require a probability distribution of the decision variable (Financial Rate of Return or NPV) (EC 2008). Therefore, a Monte Carlo Simulation for all identified critical variables (see ‘Sensitivity Analysis’ for a definition) is conducted. The evaluation report should embrace a graphical presentation of the probability distribution or the probability density function for the financial and the economic NPV. Furthermore, the confidence intervals of the target variables are to be provided. Providing the probability of a positive NPV or the standard deviation of the profitability indicator is desirable.

For project appraisals in the **United Kingdom**, the Monte Carlo Simulation is applied with a focus on costs (UK DfT 2012a). Within the ‘Quantified Risk Assessment’, costs are calculated as a function of probability, which is generated from individual risks and their probabilities of occurrence. The result of the Monte Carlo Simulation is used to give evidence about both the likely level of costs and the probabilities of cost ranges.
For small projects (costs <5 mill. GBP), it is proposed to either cluster risks into categories or to use a qualitative scale with the properties ‘very unlikely’, ‘unlikely’, ‘likely’ and ‘very likely’, instead of using continuous probability distributions. Therefore, the effort required is reduced.

The **US state of Washington** requires the conduction of workshops (see previous section on scenario analysis), which embrace Monte Carlo Simulations (WSDOT 2010). The two workshops, the ‘Cost Risk Assessment workshop’ and the ‘Cost Estimate Validation Process workshop’, consist of seven steps each. Within the first step, cost and schedule estimates are defined and reviewed or validated. Secondly, assumptions and constraints are documented, and then in the next step, the traditional project ‘contingency’ is replaced by identifiable risks. Key events are derived from detected risks within the fourth step. Possible deviations from the base estimates are quantified subsequently. The fifth stage entails a Monte Carlo Simulation in order to evaluate the collective impact of all regarded risks. The outcome reveals an estimation of reasonable range and distribution. In the sixth step, measures are discussed and defined as response to risks to the schedule that might induce increased costs. The last step is meant to ensure the effectiveness of defined measures.

Quantified Optimism Bias

General Definition

Her Majesty's Treasury (2003) defines Optimism Bias as follows: "There is a demonstrated, systematic, tendency for project appraisers to be overly optimistic. This is a worldwide phenomenon that affects both the private and public sectors. Many project variables are affected by optimism – appraisers tend to overstate benefits, and understate timings and costs, both capital and operational."

Technical and economic risks are – as outlined above – reflected in methods such as sensitivity analysis, scenario analysis or Monte Carlo Simulation; whereas "organisational, institutional, and psychological factors that promote optimism" with respect to "risks for cost increases, time schedule delays and benefit shortfalls" need to be considered separately (Flyvbjerg 2004).

As those factors are "difficult to remove totally in a complex multi player transport infrastructure planning process", Flyvbjerg (2004) distinguishes between an 'inside' and an 'outside view' on a project's appraisal. The 'inside view' is the perspective of experts and members of the project team, whereas the 'outside view' is of the perspective that does not know the specifics of the project. Where there will "always be a risk of some degree of optimism bias in the inside view", the 'outside view' uses "information on a class of similar or comparable projects … to derive information on the extent to which likely - but presently unknown – future events may increase project costs, delay project time schedule or reduce project benefits compared to the base scenario" (dto.). This method is also known as 'Reference Class Forecasting', which implies establishing "a pool of past projects similar to the one being appraised" in order to learn from experiences of past projects and to avoid 'planning fallacy' for the projects subject to appraisal (Salling and Leleur 2012).

Application examples

In **Denmark**, the optimism bias uplift is considered for investment costs and is derived with a bottom-up approach (Bickel et al. 2005; DMT 2003). Thus, a project is split into statistically independent components. Subsequently for each item a triple estimate is determined, i.e. a worst, best and most likely cost value is determined. The approach is also called 'successive calculation' as finally all items are aggregated, and a cumulative distribution function of overall construction costs is derived.

For **EU** projects, basic estimates of costs, benefits and projects' duration are adjusted by an optimism bias uplift (EC 2008).

This adjustment is based on empirical cost data of past projects (planned costs versus actual costs). As a possible approach to derive distributions of deviations from a most likely cost estimate, the 'Reference Class Forecasting' approach is mentioned.

For road infrastructure projects in **Switzerland**, the optimism bias uplifts of investment costs (including construction costs, replacement investments and cost of land) and construction time are specified (DETEC 2005). As shown in Table 3, a distinction is made between projects assessed under application of risk analysis (national or inter-regional mega projects) and projects assessed without risk analysis (small-medium projects, large regional projects).

Table 3: Optimism Bias Uplifts for road projects (DETEC 2005)

Project type	Investment costs		Construction time
	With risk analysis	Without risk analysis	
Road	≥3%	20%	20%
Tunnel, Bridge	≥6%	40%	25%

In the **United Kingdom**, investment cost estimates are required to consider optimism bias uplifts (UK DfT 2012a). The combined results of studies of Flyvbjerg (2004) and MacDonald (2002) on behalf of the UK DfT form the empirical basis of the UK's approach on how to deal with optimism bias.

Determining the optimism bias uplift for a specific project is carried out as follows. In the first stage, the project is assigned to a project type (roads, rail, fixed links or building projects). In the second step, the current stage of the project is identified. Three stages in the lifecycle of a transport project are differentiated. Finally, the determined uplift is added to the calculated costs (see Table 4). In exceptional cases, uplifts differing from the ones provided in Table 4 are used. In those cases, sufficient evidence needs to be delivered reflecting the stage of development of a project, the quality of the risk assessment conducted, and the extent to which optimism bias may or may not have been mitigated.

Table 4: Optimism bias uplift (consolidated data in UK DfT (2012a)

Category	Types of projects	Stage 1"	Stage 2	Stage 3
Roads	Motorway, Trunk roads, Local roads, Bicycle facilities	44%*	15%	3%*
Rail	Metro, Light rail, Guided buses on tracks, Conventional rail, High speed rail	66%*	40%	6%*
Fixed links	Bridges, Tunnels	66%*	23%	6%*
Building projects	Stations and Terminal buildings	51%*	-	4%*

Even though no specific uplifts are provided for operating costs, an optimism bias uplift is added. The level of optimism bias needs to be justified in the appraisal documentation, as well as any decision not to apply uplift.

Qualitative Approaches

General Definition

The application of qualitative approaches represents a deterministic risk assessment method. Two reasons suggest the application of this method to assess risk: either there is not sufficient data available to apply quantitative methods (Naumann 2007), or the effort for a comprehensive quantitative risk analysis is not proportional to the project size and budget (Her Majesty's Treasury 2004). The method is based on subjective assessment, which is mainly a result of experience and intuition (Naumann 2007).

Application Examples

In **Australia**, a broad range of questions is provided to ensure the deliverability of a project proposal (Infrastructure Australia 2010a). This qualitative approach could be considered as a checklist. Exemplary aspects covered are listed in Table 5 with a selection of questions. The checklist is supposed to ensure that risks have been formally identified and assessed. This should be documented and addressed in risk assessment reports and a risk management strategy (both peer reviewed).

Table 5: Selection of questions of the deliverability checklist of the final assessment stage (Infrastructure Australia 2010a)

Risk Type	Key Questions
Construction Risks	▪ Does the initiative pose any significant construction risks due to its location, geology, design, etc.? ▪ Are those risks reflected in the construction cost estimate? ▪ Is there sufficient capacity (including relevant skills and expertise) to ensure the delivery of the initiative and realisation of benefits? ▪ Are there any significant consequential risks to the wider network? ▪ Will delivery require associated works to enable initiative to succeed in practical terms? Especially: Who will fund the works, and how will they be delivered? ▪ How will interface risks with the initiative be managed?
Other Risks	▪ Are there any significant social or political risks? ▪ Are there any significant risks posed by (or for) other levels of government? ▪ Are there any other significant risks?

The cost estimates should consider risks, e.g. due to project location or design. Looking at construction risks, the capacity (including skills and expertise) to deliver the project as well as risks to the wider network are evaluated. 'Other risks' represent, for instance, social and political risks (e.g. risks posed by or for other levels of government).

For the case of **Spain (Junta of Andalusia)**, the qualitative assessment distinguishes between a concessionaire that operates the infrastructure after completion of the construction and the regional government, the public body involved (Junta of Andalusia 2010).

Both technical and commercial risks are considered to identify risks comprehensively and allocate them efficiently between the concessionaire and the public body involved.

The assessment of risks is based on the categories 'high', 'medium' and 'low' (dto.). In Table 6, those risk classes are assigned to all relevant risks. Furthermore, individual risks are grouped into planning risks, construction risks, availability risks and other project-specific risks.

Table 6: Selection of assessed risks, responsible party and assessment (Junta of Andalusia 2010)

Risk	Category	Responsible party	Risk impact
Errors in the drafting of the project and related activities	PR	Concessionaire	high
Cost overruns and delays	CR	Concessionaire	high
Use of building standards by third parties (constructors) below the ordinary level	CR	Concessionaire/ Public authority	moderate
Vandalism (constructions)	CR	Concessionaire	high
Archaeological discoveries (including their interruption impact on the constructions)	CR	Concessionaire	moderate
Corrections by the government/ authority to the approved concept	CR	Concessionaire/ Public authority	moderate
Risk of force majeure	CR	Concessionaire	low
Increased maintenance costs	AR	Concessionaire	high
Adjustments of currently valid regulations	AR	Concessionaire	high
Changes in legislation	AR	Concessionaire/ Public authority	moderate
Increased operating costs due to increased demand	OR	Concessionaire	low
Risks related to the financing of the project	OR	Concessionaire	high
Macroeconomic risks (inflation, etc.)	OR	Concessionaire	moderate

PR = planning risks; CR = construction risks; AR = availability risks; OR = other project specific risks

In the **US state of Washington**, assessments of projects with a budget below 10 mill. USD require a qualitative approach to deal with risks (WSDOT 2008). Risks are identified iteratively, as they “may become known as the project progresses” (WSDOT 2011).
After the identification of risks (both threats and opportunities), each risk gets assigned a probability of occurrence and the expected impact within the qualitative risk assessment. Both dimensions are categorized low or high; the probability of occurrence regarding the likelihood expected and the impact on cost, schedule, or technical issues (dto.). Categorising risks by impact and probability provides an indication on whether “substantial action” is “required to alleviate issue” (risk with high probability and high impact) or “normal management oversight is sufficient” (risk with low impact) (dto.).

RESULTS

The results of this research is twofold. Firstly, the approaches applied to cover risk by infrastructure project appraisal methodologies are synthesized. Secondly, based on identified best practises of already applied methods, an appraisal scheme is elaborated, which takes into consideration the occurrence of risks.

Synthesis of Applied Approaches

Overview of Applied Methods

Summarizing the methods applied to cover risks in transport infrastructure evaluation reveals that sensitivity analysis and scenario analysis is widely applied. Also, the Monte Carlo simulation is a relatively frequently applied method, whereas Quantified Optimism Bias and Qualitative Risk Assessment are used less often (see Table 7). The synthesis also shows that in most of the analyzed assessment schemes, combinations of methods are applied in order to cover risks.

Table 7: Synoptic overview of methodologies applied by institution

	Sensitivity Analysis	Scenario Analysis	Monte Carlo Simulation	Quantified Optimism Bias	Qualitative Risk Assessment
Australia	✓	✓	✓		✓
Canada	✓	✓	✓		
Denmark	✓		✓	✓	
European Union	✓	✓	✓	✓	
France	✓	✓			
Germany		✓[1]			
Spain (Junta of Andalusia)	✓				✓
Switzerland	✓	✓		✓	
United Kingdom	✓	✓	✓	✓	
US state of Washington		✓[2]	✓		✓

1 no scenario-wise project appraisal; 2 only required in cases, if differing opinions occur in the risk assessment process

Particularities of Applied Methods

The scope of **sensitivity analysis** applied in order to cover risks in project evaluation is determined by the (type of) variables subject to sensitivity analysis, and whether or not the estimation of switching values is part of the methodology. As shown in Table 8, sensitivity analysis is applied in all cases with respect to investment costs, and in a slightly lower number of cases, with respect of benefits and transport demand. The number and type of variables subject to sensitivity analysis differs significantly among the evaluation approaches: Whereas assessment frameworks in Australia and the EU (except for the discount rate) consider all shown variable categories, the specifications of Spain (Junta of Andalusia) only cover two variable categories.

Table 8: Variable categories considered within the sensitivity analysis and particularities

	Invest-ment costs	Exogenous factors			Trans-port demand	Monetary equiva-lents of benefits	Operating costs	Discount rate	Switching values	Particularity
		GDP	Oil price/ energy cost	Demo-graphic						
Australia	✓	✓	✓	✓	✓	✓	✓	✓		
Canada	✓		✓		✓	✓		✓	✓	Variable 'Cost estimates' not further specified
Denmark	✓				✓	✓		✓	✓	Switching value used to distinguish between project alternatives
European Union	✓	✓	✓	✓	✓	✓	✓		✓	Identification of critical values
France	✓	✓	✓		✓	✓	✓		✓	Combination of traffic volume and investment cost variation in matrix
Spain (Junta of Andalusia)	✓						✓	✓		Variation range specified per variable; Unavailability of infrastructure considered
Switzerland	✓	✓[1]			✓	✓		✓		Some variables require a new calculation of traffic forecasts, others do not
United Kingdom	✓	✓	✓	✓		✓	✓			

1 growth of wages

Scenario analysis is, in most cases, based on variables applied for sensitivity analysis, although there are also application examples in which the scenario is drafted independently from sensitivity analysis (see Table 9). In some of the application cases of scenario analysis, scenarios are applied to 'soft' alternatives to the investment project, such as regulatory or governance reforms.

Table 9: Areas of application of scenario analysis within the assessment process

	Scenario independent from sensitivity analysis	Scenario based on variables of sensitivity analysis	Particularity with respect to application
Australia	✓		▪ Analysis whether infrastructure deficits faced are expected to remain in the future ▪ Scenarios are supposed to be applied to alternative 'soft' measures (e.g. regulatory or governance reforms)
Canada		✓	
European Union		✓	▪ Scenarios are supposed to be applied to alternative 'soft' measures (e.g. regulatory or governance reforms)
France		✓	▪ Scenarios are supposed to be applied to alternative 'soft' measures (e.g. regulatory or governance reforms)
Germany			▪ Simulation of the impact of different regulatory and policy measures in three scenarios ▪ Selection of 'Integrative Scenario' as basis for all individual project assessments.
Switzerland		✓	▪ Scenarios are supposed to be applied to alternative 'soft' measures (e.g. regulatory or governance reforms)
United Kingdom	✓		
US state of Washington	✓		▪ Used to capture differing estimations during the risk assessment

Monte Carlo Simulation is applied to simulate uncertainty of investment costs and socio-economic benefits. As shown in Table 10, in the appraisal methodologies applied by Canada, Denmark and the EU, both investment costs and socio-economic benefits (determined among others by transport demand) are subject to Monte Carlo simulations.

Table 10: Field of application of Monte Carlo Simulation

	Investment Costs	Socio-Economic Benefits
Australia	✓	
Canada	✓	✓
Denmark	✓	✓
European Union	✓	✓
United Kingdom	✓	
US state of Washington	✓	

Optimism bias is applied with respect to investment costs, operating costs, socio-economic benefits, and the construction time. As displayed by Table 11, the scope of assessment variables subject to optimism bias differs between the appraisal methods. Concerning the appraisal methodology in UK and Switzerland, pre-defined assumptions on level of uplifts on cost estimates are stipulated, while in case of Denmark and the EU project-specific assumptions need to be made.

Table 11:Estimates to be adjusted by optimism bias uplifts

	Investment costs	Operating Costs	Socio-economic benefits	Construction time
Denmark	✓			
European Union	✓	✓	✓	✓
Switzerland	✓			✓
United Kingdom	✓	✓		

The variety of methods in the field of **qualitative approaches** includes risk checklist (Australia), an assessment approach with qualitative risk categories (Spain, Junta of Andalusia), and the use of a qualitative risk matrix (US state of Washington) (see Table 12). The scope of risk categories covers ranges from construction and/or planning risks to the consideration of all kinds of risks.

Table 12: Method, approach and risk categories captured of presented qualitative approaches

	Method	Approach	Risk categories captured
Australia	Risk checklist	Open questions ensure consideration of risks during the assessment process	Construction Risks, other risks
Spain (Junta of Andalusia)	Assessment with qualitative risk categories	Identification, documentation and categorization ensures efficient allocation of risks	Planning risks, construction risks, availability risks, other project specific risks
US state of Washington	Qualitative risk matrix	Risks (opportunities and threats) are assessed regarding probability of occurrence and expected impact	No categories excluded

Composition of an appraisal scheme

The analyses carried out reveal a number of methods to incorporate 'risk' in the appraisal of transport infrastructure projects. Taking into account the documented methodological frameworks, best practice approaches are highlighted.

Transport infrastructure projects vary tremendously, e.g. in terms of investment costs, level of complexity of construction, dimension of impacts on the transport sector and related sectors, or to what extent they lead to behavioural changes of involved actors. If a major infrastructure project is expected to result in behavioural changes (e.g. significant change in mode share or change in logistics structures), demand forecasts are subject to a higher level of uncertainty than for small investments without any potential to provoke behavioural changes. Therefore, as it is already practiced in France, Switzerland, the UK and the US state of Washington, the way of consideration of risk in project appraisal needs to distinguish between different types of projects. As a general principle, an infrastructure project's scope and importance for the transport and other sectors tends to increase with the investment costs. Although there may well be exceptions from this general pattern, investment cost may be used as a proxy to distinguish among different classes of infrastructure investment projects. The following considerations are developed for 'small' and 'large' infrastructure projects. Taking into account the thresholds applied by the presented appraisal schemes, a value to distinguish between 'small' and 'large' projects is an amount of investment costs of 10-20 mill. USD.

The pattern of interdependency among infrastructure projects is captured by the analysed assessment frameworks limited to a certain extent. However, the plausibility of project appraisal can be enhanced significantly if interdependency between infrastructure projects is considered in a more systematic way (see Szimba 2008). Due to the characteristics of networks, individual infrastructure projects may be interdependent with each other. If interdependent infrastructure investments are assessed independently of each other, the appraisal results are biased (see Szimba 2008; Szimba and Rothengatter 2012). Thus, forecasting transport demand for a certain project should not be carried out without consideration of potentially interdependent projects.

Small Transport Infrastructure Projects

The development of transport demand is largely dependent on exogenous factors such as demographic and socio-economic trends, international trade, or development of fuel prices. Thus, transport demand forecasts, and consequently socio-economic benefits, are significantly dependent on the underlying assumptions on exogenous trends. Therefore, drafting contrasting 'global scenarios' on exogenous evolution – as part of the project appraisal scheme in Germany – seems a useful element. In order to cover a wide range of possible future developments, these 'global scenarios' describe the following exogenous evolution pattern:

- most likely
- optimistic
- and pessimistic

In contrast to current practice in Germany, project appraisal should be computed for each of the designed scenarios. In addition, the approach followed by the EU, Switzerland, France and Australia – i.e. to identify and assess solutions, which may relieve the traffic situation by other policy measures (e.g. regulatory measures) – seems promising. It requires that each proposed infrastructure investment is confronted with the question whether equivalent results could also be achieved by alternative policies.

Taking into account that cost overruns also occur for smaller projects, the investment costs are recommended to be subject to Optimism Bias considerations on the basis of Reference Class Forecasting. This corresponds to the way the EU, Denmark, the UK and Switzerland deal with investment costs.

Transport demand is forecasted under consideration of interdependent projects (if any).

The appraisal results embrace project-specific performance measures in relation to each 'global scenario'. Furthermore, in case appropriate alternatives to the infrastructure investment exist, they include performance results for these alternatives. If there are interdependent projects, the evaluation results contain performance values under consideration of these interdependent projects.

A combination of different best practice methods for 'small' projects is summarised by Figure 4.

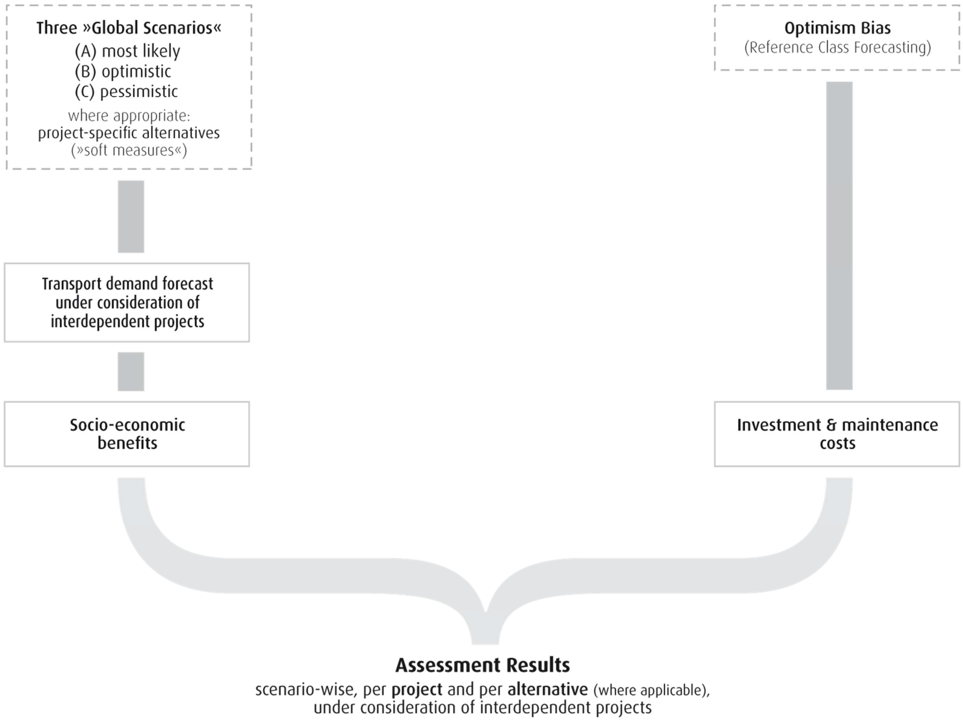

Figure 4: Overview of identified best practice with regard to 'small' investment projects

Large Transport Infrastructure Projects

In order to allow for a better consideration of uncertainties associated with larger infrastructure investments (whose possible scope exceeds that of smaller projects considerably), Monte Carlo Simulation is an adequate technique. Monte Carlo Simulation is applied in Australia, the EU, Denmark, the UK, and the US state of Washington. The EU approach implies the identification of 'critical variables', which subsequently become subject to Monte Carlo Simulation. This allows for a target-oriented application of Monte Carlo Simulation techniques for all variables, which are input to the transport forecasting model. On the side of investment and maintenance costs, Monte Carlo Simulation is recommended for all cost elements. In addition to general increase in investment costs due to Optimism Bias, as practised in several of the examined countries, the 'Quantified Risk Assessment' applied for investment cost estimates in the UK adds probabilities to all cost estimates according to quantified risks. Thus, all investment and maintenance costs are dealt with as probabilistic functions.

Likewise for small projects, the identification and assessment of 'soft' alternatives to large infrastructure projects (as far as appropriate) should be part of the project appraisal.

If a project reveals interdependence with other infrastructure projects, transport demand is forecasted under consideration of these interdependent projects.

Last, but not least, the appraisal of major infrastructure projects answers key questions as practised by project appraisal in Australia. This qualitative assessment part implies answering questions relating to construction risks, as well as to social or political risks:

- Does the initiative pose any significant construction risks due to its location, geology, design, and are those risks reflected in the construction cost estimate?
- Is there sufficient capacity (including relevant skills and expertise) to ensure the delivery of the initiative and realisation of benefits?
- Are there any significant social or political risks?
- Are there any significant risks posed by (or for) other levels of government?

If the qualitative assessment concludes that risks are expected to have serious impacts on costs or socio-economic benefits, the probability distributions underlying the Monte Carlo Simulation can be modified accordingly.

The appraisal results embrace performance values as probabilistic distributions, in relation to the project and alternatives (where applicable). If there are interdependent projects, the evaluation results contain performance values under consideration of these interdependent projects. Furthermore, the results contain a qualitative assessment report on construction risks, implementation capacity, as well as social and political risks. The combination of quantitative and qualitative assessment results provides the decision-maker a holistic and realistic view on possible project performance and creates awareness on possible risks. Figure 5 illustrates a combination of best practice methods for 'large' investment projects.

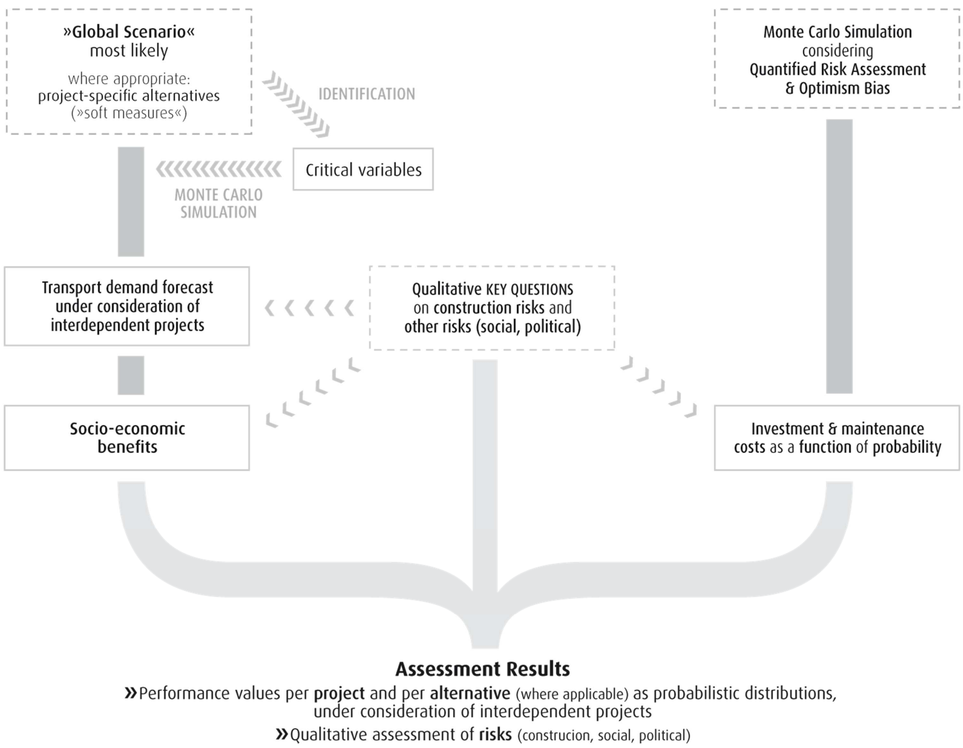

Figure 5: Overview of identified best practice with regard to 'large' investment projects

RECOMMENDATIONS FOR POLICY AND RESEARCH

The analysis of national, regional and supra-national appraisal methodologies to incorporate the pattern of risk in project assessment have revealed a wide range of different methods. While the methods presented in this paper consider risk to widely varying extent, in many national and regional appraisal schemes, proper risk assessment is not conducted: thus, risks are not considered.

The paper illustrates how an expedient arrangement of existing methodologies provides the opportunity to enhance the reflection of risk. The recommendations are largely elaborated on already practiced methods, which ensures the feasibility of the developed approaches.

In addition to the presented applied methods, several sophisticated approaches have been developed (e.g. Naumann 2007; Salling 2008; Salling and Banister 2009) and applied for individual case studies. However, in order to allow these scientific concepts (being practically applied by 'official' appraisal schemes), the assessment frameworks' methodologies and procedures need to be adjusted. In the light of research findings and recent experiences with the implementation of (major) infrastructure projects, such as Stuttgart 21, the high-speed link Lyon-Torino and the airport Berlin-Brandenburg, there is a need for transport policy to establish evaluation guidelines, which actually consider risks at the appraisal stage. Doing so will help save public funds and support them to be spent more efficiently.

Covering the occurrence of risks by supra-national, national or regional assessment framework poses several challenges for research. If the Monte Carlo technique is applied, the run time of transport demand models can still be a limiting factor; especially for network-based models, which include traffic assignment, and which embrace large complex (multi-modal) networks. Further research is required to meet the technical requirements induced by a wider consideration of risk in project appraisal. Some of the techniques to cover risk (particularly Optimism Bias using Reference Class Forecasting) require the availability of sufficient data. Cost and demand data of past projects (forecast value versus actual value) are key prerequisites to determine distributions with high confidence. Although profound research in this area has already been done (e.g. Back et al. 2000; Bain 2009; Flyvbjerg 2008; Cantarelli et al. 2010), there is a need for extensive further data collection across national borders and covering different types of projects to ensure a large data pool.

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