

Jernbanelverket Norwegian High Speed Railway Assessment Project

Contract 6: Financial & Economic Analysis
Subject 5: Uncertainty Analysis
Final Report

04/02/2011

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Contract 6: Financial & Economic Analysis

Subject 5: Uncertainty Analysis

Final Report

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Executive Summary

Atkins has been appointed by Jernbaneverket to assist in Phase 2 of its High Speed Rail (HSR) development project. The objective of the work is to identify a common basis to be used to assess a range of options for HSR development in Norway. This report provides a review of items of uncertainty which could have an impact on decisions regarding investment in HSR. This is forms the output for "Subject 5" of the Financial and Economic Analysis Contract.

Uncertainty analysis is important for major projects such as HSR in Norway because of the number of wide-ranging factors that may affect the future but which are currently unknown. HSR is developed to carry passengers on fast train services between urban centres, using conventional railway technology. While estimates can be made of how much it would cost to build a new railway today and how many people are currently travelling between any two cities by existing air or rail services, there is no certainty over how future energy costs will change, or how people's travel behaviour will be affected by attitudes towards climate change or the location of future workplaces. These factors, and many others, will therefore impact on the viability and attractiveness of HSR. Their impacts need to be understood by decision-makers rather than relying on only one view of the future.

Uncertainty analysis explicitly considers the potential impacts of risks and uncertainty on costs, benefits, performance, environmental impacts and timescales. It describes, where possible, how outcomes might vary under alternative future scenarios.

Five themes of uncertainty have been identified for this project:

- **Demographic and economic factors** – future demographic change and economic development within Norway will have a substantial impact on the future need for and demand for HSR;
- **Human factors** – both in terms of how the public will perceive and react to the construction and operation of HSR lines in Norway, and in terms of passenger reaction to the HSR product and competing modes of transport;
- **Costs of HSR and other modes** – various factors will directly influence the costs of constructing, maintaining and operating HSR, as well as the costs to the passenger of HSR and other competing or complementary modes of transport;
- **Construction solution and technology for HSR** – HSR technology is evolving rapidly internationally and the way in which this can be applied in Norway is a major consideration;
- **Policy and legislative background** – the case for HSR development sits within wider Government policy on transport, energy, land use planning, environment and other issues – and this may change in the future.

Alongside these themes of uncertainty sit those project risks that are internal to the HSR project in that they can be influenced or managed by the actions of those developing and implementing the project. While major risks are identified under some of the themes of uncertainty, internal project risks are considered explicitly in the risk register developed under Subject 2 of the Financial and Economic Analysis Contract, Estimation and Assessment of Investment Costs.

Decision-making in the face of risk and uncertainty can be supported by a number of tools that are applied at different stages in the business case development process:

- **Quantified Risk Assessment (QRA)** – this is normally applied to cost estimation, where the key risks can be identified and their probability and impacts estimated;

- **Reference class forecasting** – this is normally applied through the use of ‘optimism bias’ adjustments for mega-projects, to ensure that experience from elsewhere is reflected in project cost estimates;
- **Sensitivity testing** – this is mainly applied to demand, economic and financial modelling, to identify the key factors that have most impact on the business case;
- **Scenario planning** – where alternative scenarios of the future are used to identify a potential range of outcomes, particularly where several interacting factors are uncertain.

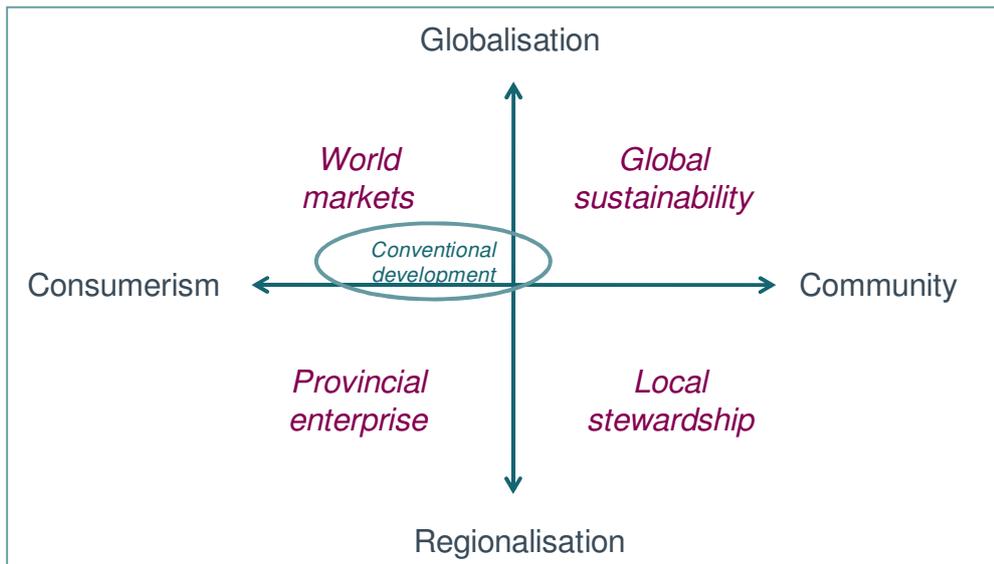
QRA and optimism bias adjustments will be needed mainly for cost risks and uncertainties and are discussed further in separate reports (the Estimation and Assessment of Investment Costs report and the Economic Analysis report). The sensitivity tests to be carried out in Phase 3 of the project are recommended to include:

- Rate of population growth;
- Rate of economic growth;
- Passenger perceptions on the attractiveness of HSR;
- Passenger mode choice behaviour;
- Transport prices (or fares) for HSR and other modes of transport;
- The cost and attractiveness of air travel;
- The cost and attractiveness of car travel;
- Enhanced performance of HSR, including operating speed, reliability, capacity, cost;
- Impacts of climate change on HSR construction and operation;
- The impact of key complementary transport projects.

There are certain major uncertainties that require scenario planning analysis to consider their full range of effects on the case for HSR:

- The rate and pattern of economic growth;
- Patterns of travel demand and how these might be affected by shifts in attitude and/or communications technology;
- The cost and security of supply of oil and electricity;
- Public policy on transport development and energy.

It is also recommended that in Phase 3 alternative future scenarios are developed to allow these uncertainties to be considered. A set of scenarios based on two axes of change – governance scenarios and social values (demonstrated overleaf) – could be developed and used. These scenarios enable the complex interactions of travel behaviour, the costs of different transport modes, environmental impacts and travel pricing to be assessed.



In Phase 3, developing these scenarios in greater detail, establishing assumptions for key parameters and examining the range of impacts will allow a good understanding of the key factors that will influence the case for HSR in Norway.

1 Introduction

1.1 Background

Jernbaneverket has been mandated by the Norwegian Ministry of Transport and Communications to assess the issue of High Speed Rail (HSR) lines in Norway. There is a National Transport Plan covering the period from 2010-2019 which includes relatively minor enhancements to the railway network. The ministry wishes to understand if going beyond this and implementing a step change in rail service provision in the form of higher speed concepts could “contribute to obtaining socio-economically efficient and sustainable solutions for a future transport system with increased transport capacity, improved passability and accessibility”.

Previous studies have been carried out looking into HSR in Norway and there are various conflicting views. The aim of this study is to provide a transparent, robust and evidence based assessment of the costs and benefits of HSR to support investment decisions.

The study has been divided into three phases.

- In Phase 1, which was completed in July 2010, the knowledge base that already existed in Norway was collated, including outputs from previous studies. This included the studies that already were conducted for the National Rail Administration and the Ministry of Transport and Communication, but also publicly available studies conducted by various stakeholders, such as Norsk bane AS, Høyhastighetsringen AS and Coinco North.
- The objective of Phase 2 is to identify a common basis to be used to assess a range of possible interventions on the main rail corridors in Norway, including links to Sweden. The work in Phase 2 will use and enhance existing information, models and data. New tools will be created where existing tools are not suitable for assessing high speed rail.
- In Phase 3 the tools and guiding principles established in Phase 2 will be used to test scenarios and options on the different corridors. This will provide assessments of options and enable recommendations for development and investment strategies in each corridor.

This report is a component of the Phase 2 work.

The principles established in Phase 2 are to be used to test four scenarios:

- Scenario A – reference case. This is a continuation of the current railway policy and planned improvements, with relatively minor works undertaken shown in the National Transport Plan from 2010-2019. This forms the ‘do minimum’ scenario to which the other scenarios will be compared;
- Scenario B – upgrade. A more offensive development of the current infrastructure, looking beyond the ‘InterCity’ area;
- Scenario C – major upgrades achieving high-speed concepts. This is to be based on an aggressive upgrade of the existing network to provide a step change in journey times; and
- Scenario D – new HSR. This involves the implementation of newly built, separate HSR lines.

The improvements are being considered on six corridors:

- Oslo – Bergen;
- Oslo – Trondheim;
- Oslo – Kristiansand and Stavanger;
- Bergen – Stavanger;
- Oslo – Stockholm (to Skotterud in Norway); and

- Oslo – Gothenburg (to Halden in Norway).

The scenarios will be considered in relation to the long distance travel market, for example for journeys over 100km in distance. Other studies, such as the InterCity Study will look at initiatives for shorter distance travel at a more regional level. Various route alignments, stop patterns, station designs, speed standards and fares will be tested. It will be necessary to assess conditions related to income and costs, environmental concerns, energy consumption, maintenance under winter conditions and the procurement and operational organisation of the services and infrastructure.

1.2 Overall Context of Contract 6 (Financial and Economic Analysis)

To achieve Phase 2 of the study, Jernbaneverket has commissioned six Contracts:

- Technical and Safety Analysis;
- Rail Planning and Development;
- Environmental Analysis;
- Commercial and Contract Strategies;
- Market Analysis; and
- Financial and Economic Analysis

WS Atkins International Ltd (Atkins) is assisting Jernbaneverket in two of the contracts: Market Analysis and Financial and Economic Analysis. This report is part of the Financial and Economic Analysis Contract.

The Financial and Economic Analysis Contract consists of five Subjects:

- Subject 1 Impact on Road and Aviation Sectors;
- Subject 2 Cost Estimation;
- Subject 3 Funding and Operating Structure Analysis;
- Subject 4 Financial and Economic Analysis; and
- Subject 5 Uncertainty Analysis

The purpose of the Financial and Economic Analysis Contract is to establish an assessment framework to use to evaluate potential HSR options against the objectives stated in the Ministry's mandate. Outputs of the assessment framework will show the financial impact and affordability of the interventions, including an evaluation of alternative financing options. Socio-economic impacts of the improvements will also be demonstrated and together with forecast generated revenue will be considered in relation to the expected costs. The uncertainty around the results will be assessed. Together the outputs will provide a basis for HSR investment decisions in Norway.

This report provides the outputs for Subject 5.

1.3 Purpose of Subject 5 (Uncertainty Analysis) Report

The purpose of the Subject 5 Uncertainty Analysis report is to understand and assess items of uncertainty which could have an impact on the decisions regarding High Speed Rail (HSR) investment. Such items of uncertainty are likely to affect the costs, the benefits or deliverability of the investment. The potential impact of the key uncertainties are discussed and tools to aid decision-makers are presented.

1.4 Organisation of Report

The remainder of this Uncertainty Analysis report contains the following sections:

- Chapter 2 describes why uncertainty analysis is required, discusses risk and uncertainty and presents a set of uncertainty analysis tools to aid decision-making;
- Chapter 3 presents the major uncertainties for Norway HSR, identified through background research, a project-wide risk workshop and experience of other HSR projects;
- Chapter 4 makes recommendations for treatment of the major uncertainties identified and develops four scenarios for use in a future scenario planning exercise;
- Chapter 5 draws together conclusions from the uncertainty analysis report.

2 Purpose of Uncertainty Analysis

2.1 Introduction

This Chapter describes uncertainty and risk in the context of the assessment of major projects such as Norway HSR. An explanation is provided of why uncertainty analysis is required and the tools for handling it in the Norway HSR project are outlined.

2.2 Why uncertainty analysis is required

Conventional forecasting and appraisal methodologies tend to start from the position that a view of the future can be developed from existing factors and trends, projected forward. This results in one future outcome or scenario, broadly consistent with the current situation. Explicit consideration of risk and uncertainty, on the other hand, allows for the possibility of there being more than one outcome in the future. When considering a major project, such as the development of an HSR system, the impact of risks and uncertainties on the business case for the project, need to be understood and considered in investment decision making.

While the term 'risk' is often used to describe a threat, or an event with negative consequences, risks and uncertainties can also have positive outcomes. The term 'risk' tends to be used for events that are measurable and identifiable, whereas under 'uncertainty' the range of outcomes and their likelihoods of occurring can be unknown. In the case of uncertainty, there may also be incomplete knowledge about the present.

There can be considered to be a continuum from uncertainty to risk to certainty, as illustrated in Figure 2.1. In any event, there are considerable overlaps between these three areas and in reality, there are no clear dividing lines, but rather varying degrees of certainty. The key risks and uncertainties of any project are likely to change over time as the project develops – further information becomes available, or policies are implemented, for example, which remove some of the uncertainties, but equally, new risks may emerge.

Figure 2.1 – Risk and uncertainty



The purpose of understanding risk and uncertainty is to allow Jernbaneverket and policy-makers to make sound and well-informed decisions on HSR in Norway. More specifically:

- To understand the range and likelihood of potential costs, benefits and wider implications of different courses of action;
- To understand the interactions with policy decisions in other areas.

As examples of high-level risks and uncertainties that may affect decisions on HSR:

- Unforeseen geological conditions may require local design changes to the HSR route and hence introduce cost increases and delay construction timescales. The likelihood and impact of these kinds of specific project risks should be reflected in cost estimates and economic cost-benefit analyses, in order that the costs of HSR construction are not underestimated;
- The price of air fares may change from current levels, which could increase or reduce the demand for HSR compared to the forecasts. While it may be difficult to estimate the future level of air fares with great confidence, the underlying influences on air fares, such as gasoil prices or government policy on subsidising the regional air sector, can be identified and a plausible range of impacts assessed. In this way, the impact on the HSR economic case of external influences or government policy in other areas can be understood.

This report focuses on identifying the major uncertainties that affect HSR in Norway. Internal project risks, which can be identified and managed by the project promoter or developer, are also important, but are considered in more detail in the Subject 2 Cost Estimation Report.

2.3 Uncertainty analysis tools

There are various tools that can be used in projects such as this to support decision-making in the face of risk and uncertainty:

- **Quantified Risk Assessment** – this is normally applied to cost estimation, where the probability and impact of key risks are both known, and can be estimated;
- **Reference class forecasting** – which is particularly applicable and important for ‘mega-projects’. The probability and impact of risk can be inferred from experience of other similar projects. In the UK, this is applied through the use of ‘optimism bias’ adjustments (discussed fully as part of the Subject 4 Economic Analysis report);
- **Sensitivity testing** – which is mainly applied to demand, economic and financial modelling, in order to identify the range that surrounds benefits or costs under different circumstances;
- **Scenario planning** – where alternative scenarios of the future are used to identify a potential range of outcomes, where several interacting factors are uncertain.

2.3.1 Quantified Risk Assessment

A Quantified Risk Assessment (QRA) provides estimates of the range of likely outcomes around a central estimate. It normally follows a four-stage process of (i) risk identification, (ii) assessing the impacts of risks (cost or programme delay), (iii) assessing the likelihood of the impacts of the risks and (iv) quantifying the distribution of risk and expected values. This is best carried out when a project is well-defined and the risks are readily identifiable and are understood, such as when estimating the costs of a major capital project.

The outcome of a QRA will be a probability distribution that provides an assessment of the expected value of the project cost, taking into account the likelihood and impact of all the identified risks. It also allows identification of the risks that will have the most severe impacts on timescales and/or costs in order that appropriate risk management strategies can be adopted. The framework for achieving this will be set up as part of Subject 2 – Cost Estimation.

2.3.2 Reference class forecasting

The use of reference class forecasting is becoming more widespread, particularly for public sector projects. Rather than systematically identifying project-specific risks, as is done for QRA, it predicts outcomes based on experience from similar projects – or a reference class of projects.

The original theorists¹ behind reference class forecasting found that, particularly on 'mega-projects', planners tend to under forecast costs and overestimate benefits systematically because information on the distribution of outcomes is not taken into account.

Where data is available, the three stages of reference class forecasting are (i) identify a reference class of past, similar projects, (ii) establish a probability distribution for the selected reference class for the parameter that is being forecast, and (iii) compare the specific project with the reference class distribution, in order to establish the most likely outcome for the specific project. In the UK, this approach has given rise to the use of 'optimism bias' adjustments for the costs of public sector transport projects, based on work by Mott Macdonald and Flyvbjerg et al. Adjustments are made to project costs according to the type of project and its stage of development. This has been discussed in a note which will support the Subject 4 Economic Analysis report. We recommend that optimism bias is included in a sensitivity test in the economic analysis.

By dividing a project into independent parts and applying reference class forecasting techniques to the individual parts, the use of optimism bias adjustment can be restricted to the areas where uncertainties are greatest, thus not affecting parts or areas where uncertainty is acceptable or where greater detail is available for other techniques such as QRA.

2.3.3 Sensitivity testing

Where there is a set of possible outcomes but their probability of occurring is unknown, or where applying QRA is too complex because of many factors that interact, then sensitivity testing may be the appropriate tool. Sensitivity testing is commonly applied to forecasts of demand, revenue or benefits where there is uncertainty around an input assumption (such as GDP growth) and its effects are relatively complex to establish, often requiring a run of a demand or economic model.

In order to carry out a sensitivity test, plausible ranges are applied to input assumptions in order to establish the range of potential outcomes for the final forecast variable. In this way, the assumptions that have the most impact on the forecasts can be identified and the overall robustness of the business case can be assessed.

2.3.4 Scenario planning

Scenario planning is a process of assessing the impact of different future events by considering alternative possible scenarios. It recognises, unlike sensitivity testing, that factors interact in complex ways and considers the combined effects of many factors. It also recognises the potential impacts of true uncertainties that are difficult to predict, such as new technological inventions (e.g. the development of the internet) or shifts in people's values (e.g. the rise of environmentalism), as well as more established and more easily forecasted trends. Originally used in business planning by Shell, its use has developed across the business and academic world, although its use in rail planning projects is not yet widespread.

The UK Cabinet Office² states that "Good scenarios:

- Are based on analysis of change drivers
- Allow critical uncertainties and predetermined elements to be distinguished
- Are compelling and credible
- Are internally logic and consistent."

¹ Flyvbjerg, B., 2006, "From Nobel Prize to Project Management: Getting Risks Right." Project Management Journal, vol. 37, no. 3, August, pp. 5-15.

² http://interactive.cabinetoffice.gov.uk/strategy/survivalguide/skills/eb_scenarios.htm

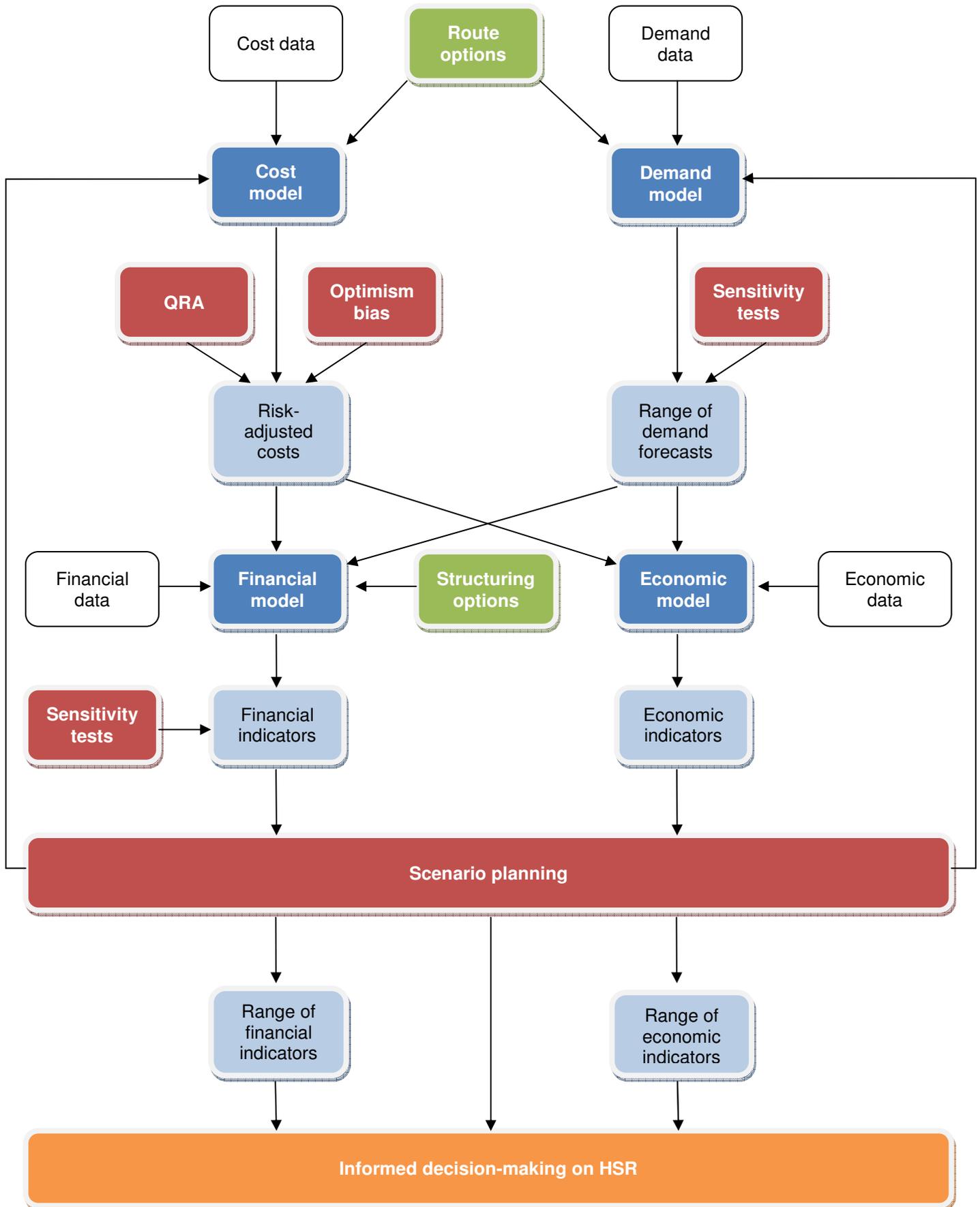
For practical reasons, a small set of scenarios is normally developed and often four illustrative scenarios are considered, with variations along two axes representing very different drivers of change.

2.4 Uncertainty analysis tools in the business case development process

The way the uncertainty analysis tools described above fit into the business case development process is outlined in Figure 2.2 overleaf. Sensitivity testing, QRA and optimism bias adjustments are normally applied to individual cost and benefit variables in the relevant cost, demand and financial models. Under scenario planning, however, all inputs to the appraisal process need to be considered in order to develop a plausible and holistic alternative future scenario and to understand the implications on the overall case for HSR. Sensitivity testing and scenario analysis tools are of particular use in understanding the potential impacts of major uncertainties.

The use of QRA and a project-specific risk register is described further in the Subject 2 Cost Estimation Report. The market analysis and demand forecasting tools are described further in the Market Analysis Subject 1 (Demand Forecasting) report. The financial modelling process is described in the Subject 3 Funding and Operation of Infrastructure Report and the economic models are described in the Subject 4 Economic Analysis Report.

Figure 2.2 – Uncertainty analysis tools



2.5 Conclusions

Uncertainty analysis is an important process in decision-making on major projects because of the inherent uncertainties in forecasting the future. Conventional tools will use present conditions as the starting point, but it can be critical to ensure that decision-makers are clear on the circumstances under which outcomes may change significantly from the central forecasts.

There are different tools that can be used in the business case development process for different types of uncertainty. The following chapter describes the major uncertainties affecting the development of HSR in Norway and this will be followed by recommendations on how these uncertainties could be handled through the tools identified here.

3 Elements of uncertainty

3.1 Themes of uncertainty

This Chapter of the report describes the key elements of uncertainty that have been identified in relation to HSR in Norway. These elements have been identified from background research, from experience of HSR in other countries and from the project risk workshops held on 23/24 November 2010.

The uncertainties are categorised into five themes, described below, by considering the types of external factor that may influence the outcomes of HSR projects on the basis of their underlying drivers, such as demographic change or technological development.

The uncertainties noted under each theme will have a range of potential impacts on the development of HSR and so each will need to be treated differently during the project development period. The potential impacts are noted below and recommendations for treating each uncertainty are made in Chapter 4.

The five themes of uncertainty identified are:

1. Demographic and economic factors
2. Human factors
3. Cost factors
4. Technology factors
5. Policy and legislative factors

Under each theme of uncertainty will be a number of specific uncertainties and risks: some of these can be quantified, others cannot be quantified at this stage. There will be interactions between some uncertainties. For example, energy costs will affect public transport fares (and hence demand) and also the cost of operation of HSR and competing modes, which will affect the business case for HSR and the scale of services that can be operated economically.

3.2 Internal risks

Alongside the five themes of uncertainty, there are also risks that are internal to the HSR project. These project risks are influenced by the actions of those promoting, developing and implementing the project rather than by external agencies or events and so are separated from the (external) uncertainties as to an extent they can be managed by the project promoter and/or client. Nevertheless, they represent significant risks to the project and need to be acknowledged during the development of the case for HSR and managed actively during implementation.

The risk register developed under Subject 2, Estimation and Assessment of Investment Costs, identifies the key project risks that are likely to affect the development, construction and operation of HSR in Norway. The Risk Register (described separately in the Subject 2 report), identifies risks during all stages of an HSR project:

- Stage 1 – Pre Feasibility;
- Stage 2 – Option Selection;
- Stage 3 – Design development.

Examples of the risks that are identified in the risk register include:

- Property prices are greater than anticipated, because of economic climate or developers' actions, leading to increased project costs and delays in reaching agreements;
- Failure to achieve planned rate of construction progress because of unknown ground conditions;
- Tunnel fire during operational stage, because of inadequate project controls.

These risks will be dealt with in the QRA framework being set up under Subject 2.

There will also be internal decisions (yet to be made) on how to carry out the project, such as financing strategy – while these are currently uncertainties, decisions on these issues can be made in the future, and these decisions will be informed by analyses to be carried out at later stages of the project.

3.3 Theme 1: Demographic and economic factors

Future demographic change and economic development within Norway will have a substantial impact on the future need for and demand for HSR. Table 3.1 sets out the major uncertainties under this theme.

Table 3.1 – Demographic and economic factors

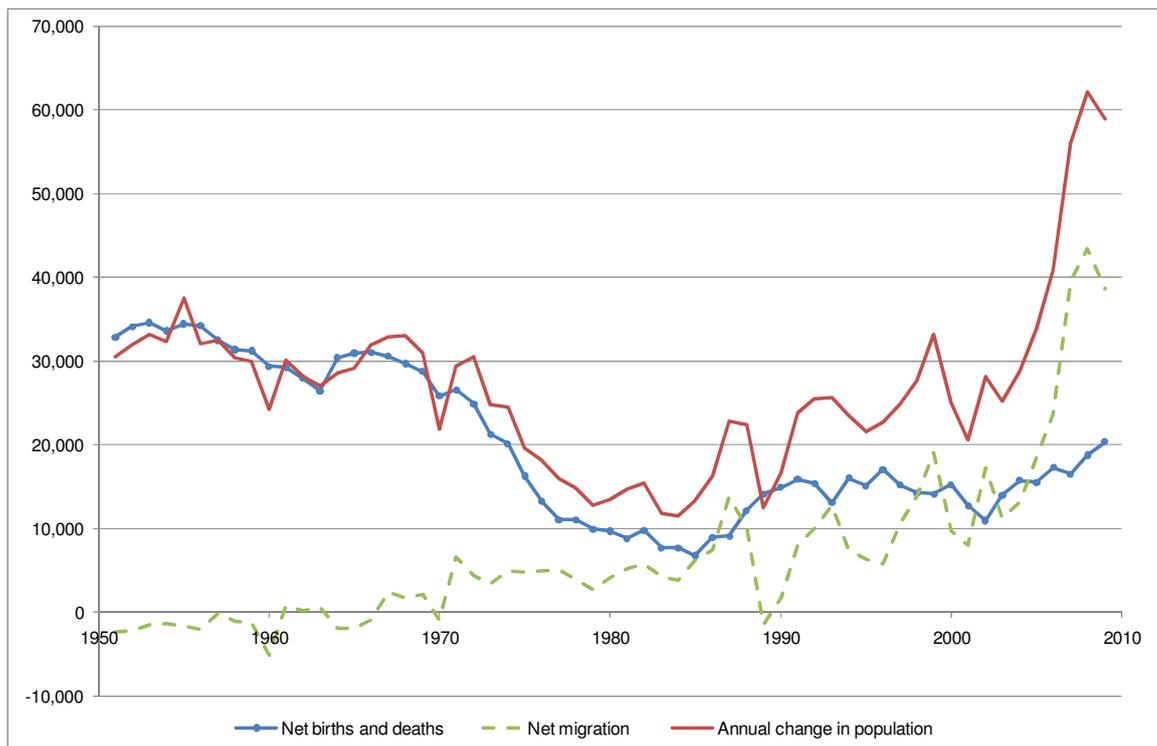
Uncertainty	Description
Rate and distribution of population growth	Population growth patterns and demographic patterns, including immigration rates and land use influencing where people live, will significantly affect the need for HSR and future demand levels.
Rate and distribution of economic growth	Economic growth rates and distribution of wealth will significantly affect the need for HSR and future demand patterns.
Employment levels and patterns	Employment levels and patterns will particularly affect business demand for HSR.
Current travel patterns on existing modes	Accuracy and consistency of base data is not certain e.g. current demand, volumes using other modes, influencers of modal shifts, interconnections between modes and services.
Relationship between population, employment and economic growth and rail demand	Current relationships can only be estimated. Patterns may change in future due to factors such as carbon concerns or changes in working habits.
Future patterns of leisure travel	Influenced by relative attractiveness of Norway as a tourist destination for domestic or international passengers, and the attractiveness of travelling to outside Norway for tourism.
Future patterns of business travel	Business travellers' needs may change in future as communications technology develops.

Population, employment and economic growth are key drivers of travel demand. The demand analyses being prepared for the Market Analysis Contract uses projections of these underlying drivers to generate forecasts of future travel demand. There are inevitably uncertainties over

future demographic and economic change, some of which will be affected by international patterns of migration or global economic activity. Other changes will be more local, although may impact on the demand for HSR by affecting the number of people living in certain urban centres within accessible distances of a transport hub.

Population in Norway, currently at 4.8 million, has grown by nearly 50% since 1950, an average increase of 0.7% per annum. The annual growth rate has fluctuated between 0.3% and 1.3% and over the years the influence of net migration levels (largely from higher levels of immigration) has increased substantially, compared with the impacts of net births and deaths, as Figure 3.1 illustrates.

Figure 3.1 – Population change 1951-2010, Norway



Source: Statistics Norway

The distribution of population growth is important in terms of travel demand, with urban population being much more likely to access HSR, in large part because of proximity to stations. Over the last decade, population growth has been higher within cities – Oslo, Stavanger, Trondheim and Bergen – than outside cities. This will tend to stimulate HSR demand. Other trends that will have had an impact on demand levels include the long-term shift of population from municipalities in the north and north-west to the rest of the country.

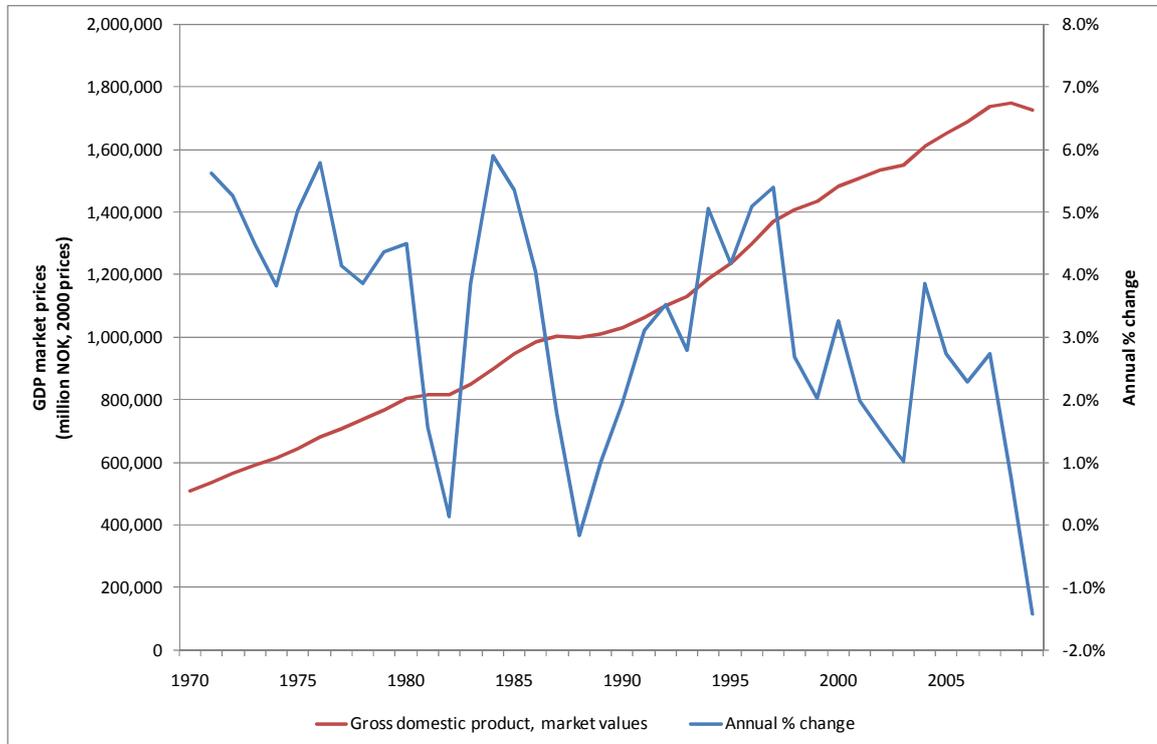
Population projections from Statistics Norway show an annual average growth rate of 0.9% through to 2030, with higher growth rates forecast for cities such as Oslo, with an annual average growth of 1.3%, compared with northern areas such as Finnmark, where negligible growth is forecast.

Employment levels also influence the demand for travel, and as with population levels employment statistics show some significant differences from area to area. Since 1996, the number of employed persons in Norway has increased by 18%, but the growth has been much more marked in areas such as Oslo, with 44% growth, than some of the more rural areas in the north.

The rate of economic growth varies considerably from year to year, as Figure 3.2 shows. Over the last 40 years, the annual rate of growth has fluctuated between 5.9% in 1984 to -1.4% in

2009. However, the impact on the overall level of GDP is more muted, with the total GDP line in Figure 3.2 looking relatively stable when looking beyond the short-term economic cycle. The average annual growth rate over this period was 3.2%. While there have been relatively wide fluctuations in this growth rate over short periods of time the overall trend has been positive over the long term, albeit with somewhat lower levels of growth in recent decades.

Figure 3.2 – GDP growth 1970-2009



Source: Statistics Norway

Forecast GDP to 2030 from Statistics Norway shows an average growth rate of 2.3% over the next 20 years. Higher growth rates are forecast through to around 2017 as the economy recovers from recession, with the growth rate then evening out at around 2% per annum.

The relationships between these underlying drivers and travel demand are established from historic research on travel behaviour. The growth section in the separate report on Demand Forecasting (Market Analysis Subject 1) documents the underlying assumptions for growth, which assume that current relationships between economic factors and travel demand will continue into the future.

However, it is possible that these relationships will shift in the future as consumer behaviour changes over time, perhaps in response to factors such as increased concerns over climate change or the impact of communications technology. Depending on the breakdown of information available on the parameters and elasticities underpinning the 'NTM 5' model, this may be able to be reflected in the Phase 3 work by changes to the demand elasticities for different types of passenger, and perhaps in differences between different modes of transport.

3.4 Theme 2: Human factors

Human factors arise both in terms of how the public will perceive and react to the construction and operation of HSR lines in Norway and in terms of passenger reaction to the HSR product and competing modes of transport. Table 3.2 sets out the major uncertainties under this theme.

Table 3.2 – Human factors uncertainties

Uncertainty	Description
Public reactions to environmental effects from construction of a new route	Visual, noise, vibration, other environmental impacts may be seen as unacceptable at local level, compromises in scheme design may be required and/or additional costs.
Public reactions to public funding required for HSR	Funding requirements may be seen as unacceptable and not justified by economic case. There may be a push towards lower cost alternatives. There may be objections during planning process leading to delay or changes to the scheme.
Passenger perceptions of HSR and its attributes, which affect the forecast demand for HSR	Reactions to journey time, frequency, reliability improvements are uncertain and may change over time. Willingness to pay may not be assessed correctly as HSR is a new mode of transport. Image and popularity of HSR may be influenced by appetite for HSR development in rest of Europe. Length of time to establish familiarity with HSR (a new mode of transport) is unknown.
Passenger priorities over choice of HSR or different modes, which affects the forecast demand for HSR	Current determinants of mode choice between HSR and other modes are uncertain.
Perception of safety and security of HSR, also affecting demand forecasts	Perceptions of safety and security on HSR in comparison with other modes will affect demand.
Passenger perceptions of environmental performance of HSR, potentially affecting forecasts of demand for HSR and other modes	Perceptions of HSR environmental performance in comparison with other modes will affect demand.

The development of new HSR lines, whether by upgrading existing lines or constructing new, will involve substantial railway construction works and significant public expenditure. The public will have a view on the local desirability of construction projects, much of which will take place in open countryside, and on the funds necessary to finance such projects. There is inevitably a political dimension to such major projects – whether at the local or national level. Public opinion will influence decision-makers and politicians and will therefore have an impact on HSR development, whether this be through demands to mitigate local impacts (and hence the imposition of additional costs) or by pressures to reduce costs and phase development over a longer period to ease pressures on public finances. There may also be pressures to focus public funds in other sectors, such as healthcare or road improvements, where it may be considered to provide greater benefits.

There is currently a wide range of political opinion in Norway on HSR. Active promoters of HSR include the socialists (SV), while Fremskrittspartiet (the Progress Party) is strongly opposed to HSR (and also to the current study). Other parties (such as the Norwegian Labour party and the Conservative party) are more divided. Many have the view that Norwegian oil revenues should

be invested in Norway, rather than overseas funds, which may support HSR development in Norway – or may give rise to concern over possible reliance on international suppliers.

Even among organisations that support HSR, there are different views. Norsk Bane is promoting the development of HSR in Norway, but has argued against the current study and in favour of work it commissioned from Deutsche Bahn, which it believes to present a more independent evaluation.

There is already some information on passengers' responses to HSR. A study by Urbanet Analyse³ of airline passengers' reactions to HSR found a very favourable response to HSR due to the potential time advantages of HSR travel, given that only 20% of the time for an air trip is actually spent on the flight, and because of the opportunities to work productively on the train. The research estimated that the HSR market share from Oslo to Bergen, Trondheim or Stavanger could be between 75% and 95%. However, the survey only examined air passengers and the results were dependent on the HSR service offering, so it does not necessarily represent a comprehensive assessment of passenger reactions.

Current passenger preferences and likely behaviour when faced with different travel choices are being probed systematically and in detail through the Stated Preference survey being carried out under the Market Analysis Contract. This is examining respondents' attitudes to time, cost, comfort, ability to work, security, luggage and group travel compared with their current mode of travel.

Passenger priorities will also be influenced by income levels (as discussed under the demographic and economic uncertainties theme) and by less tangible influences such as perceptions of relative environmental performance or safety of different modes. These factors are likely to have a significant impact on the long-term demand for HSR.

3.5 Theme 3: Costs of HSR and other modes

Cost factors will directly influence the costs of constructing, maintaining and operating HSR, as well as the costs to passengers of HSR and other competing or complementary modes of transport. Table 3.3 sets out the major uncertainties under this theme.

Table 3.3 – HSR cost uncertainties

Uncertainty	Description
Exchange rates or interest rates	Rates may change during project, affecting HSR project costs.
Construction sector price inflation	Prices may change during project, changing HSR project costs relative to costs in other sectors.
Electricity sources and costs	Changes in cost of power will affect HSR costs (and fares). Source of power generation will affect costs and environmental performance (carbon emissions from HSR).

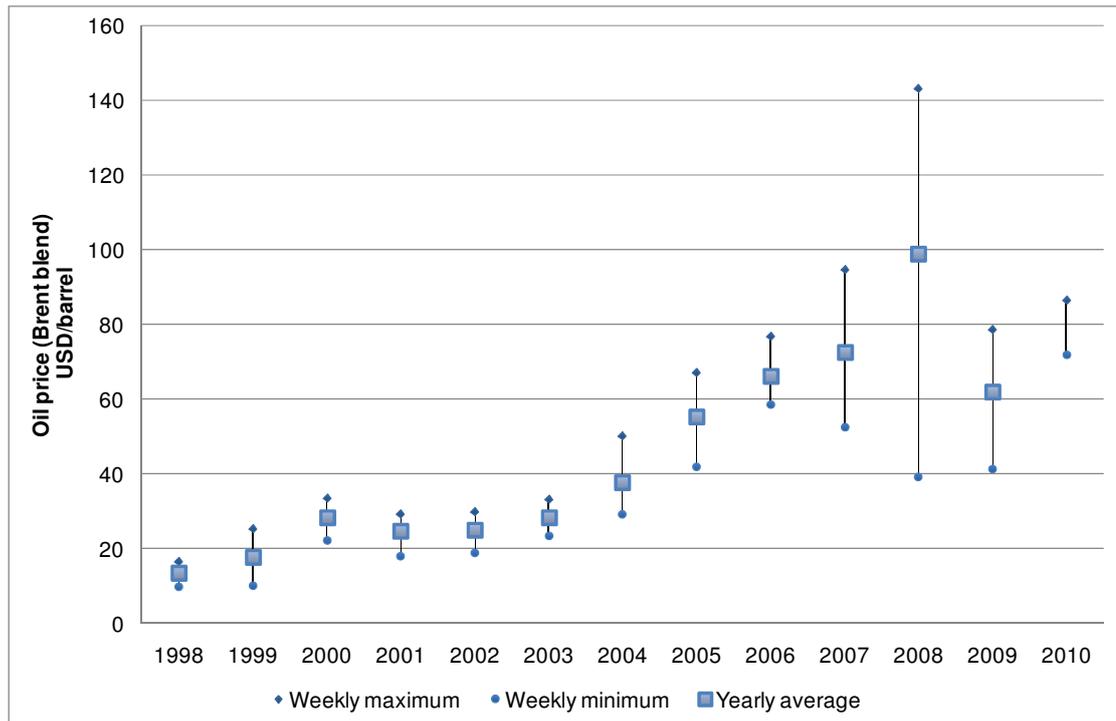
³ http://www.urbanet.no/media/publiseringer/UA_rapport_12_2009_HH_tog_APRIL.pdf

Uncertainty	Description
Cost of oil/energy	Changes in cost of oil will affect prices charged for competing modes (air, car, coach, ferry, existing rail). There will also be a second-order impact on the cost of HSR.
Energy supply or future shortages	Potential energy distribution problems in Norway (power lines, middle Norway/Troendelag especially) affect cost of HSR. A number of high voltage line projects are proposed to address unsatisfactory distribution capacity, especially on the west coast and Troendelag.
Change in costs of raw materials	Commodity prices (steel, aluminium, other precious metals) – will affect cost of construction and maintenance of HSR.
Future salary/wage costs	Changes in salary costs will affect both cost of constructing, operating and maintaining HSR (and alternative competing modes) and passengers' willingness to pay for HSR.
Government policy on transport prices	Policy on HSR fares, price regulation or pricing policy on other modes of transport will affect demand and revenues.
Future prices for competing modes (air, coach, car, ferry) may change - because of underlying cost changes	Influences demand, revenue and benefits.
Developments in aviation sector	Change in competitiveness and attractiveness of air travel may arise from new technical or product developments or changing practices (e.g. air travel times affected by security checks, or improved efficiency of operations).
Developments in road sector	Change in attractiveness of private car or coach travel because of road improvements, road pricing, competitive behaviour, automotive technology advances.

There is a wide range of external factors that will affect the costs of constructing and operating HSR in Norway, many of which, such as the costs of raw materials or exchange rates, are influenced by international economic events.

The price of oil, even though Norway is a large producer, is governed by international markets and will impact on HSR construction costs through the costs of transporting materials and labour, and on HSR operating costs in as far as oil prices influence electricity prices. Figure 3.3 shows international oil prices since 1998, illustrating reasonably steady prices at \$20-30 per barrel until 2003 but considerable increases since then, together with significant fluctuations, particularly in 2008.

Figure 3.3 – Oil prices Jan 1998 – Sept 2009

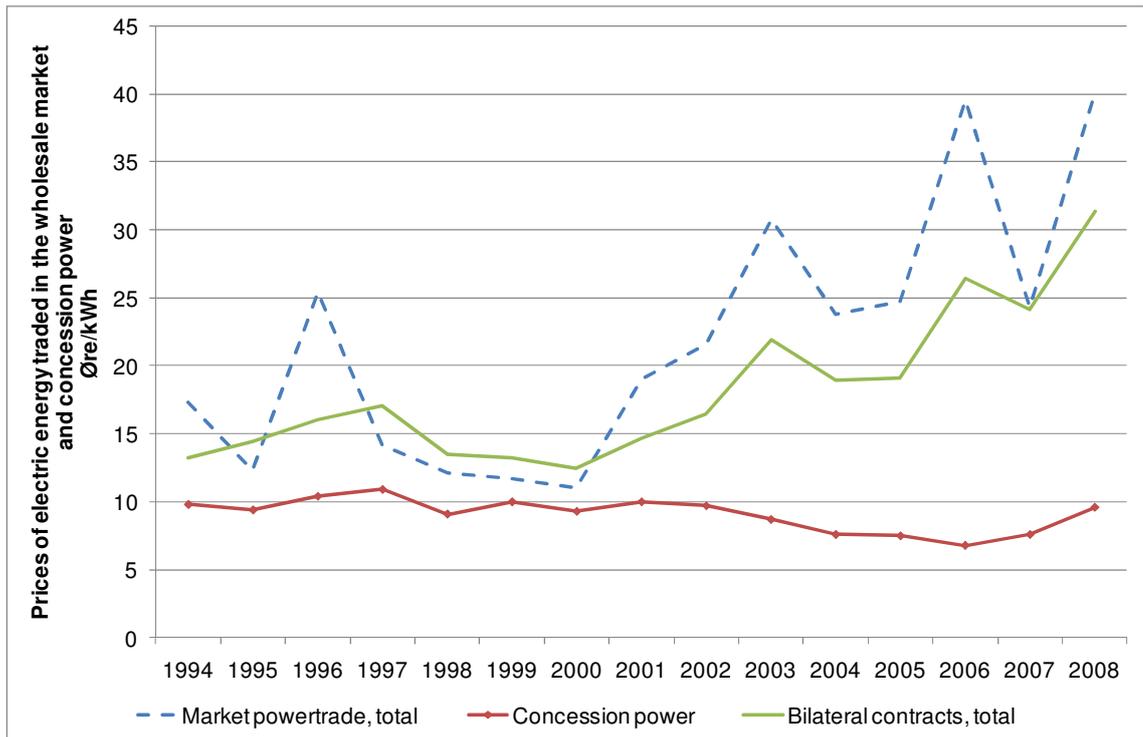


Source: Statistics Norway. Prices are weekly averages for Brent Blend, which is a benchmark for oil production from Europe.

As oil demand inevitably increases internationally in the coming years, and peak oil production is reached, the impact on oil prices cannot be certain, although further price rises and substantial volatility can be expected. This will have significant effects on the costs of air, road and ferry-based transport modes, which compete with HSR, but will also affect HSR costs to a lesser degree.

HSR trains will be powered by electricity, which in Norway is currently generated from hydroelectric plants and therefore has a low carbon impact. The extent to which this supply can be guaranteed for the future is a key issue, as is the extent to which prices are affected by levels of local rainfall (which in turn may be affected by climate change). The production of electricity in Norway has increased since the 1950s from around 17,000 GwH per annum to nearly 130,000 GwH, mostly by expanding hydroelectric production. High voltage cables to Sweden, Denmark, the Netherlands and Germany allow for the transfer of electricity in periods of over- or under-production. Prices in Norway (and carbon emissions at the margin) are therefore also influenced by prices in continental Europe where electricity production is largely based on oil, gas and coal. Prices can be managed to a degree through long-term electricity contracts, to mitigate short-term fluctuations. Figure 3.4 shows indicative average prices for electric power, the 'market powertrade' line illustrating the higher prices and greater fluctuations experienced in energy that is internationally traded within Scandinavia.

Figure 3.4 – Prices of electric energy in Norway

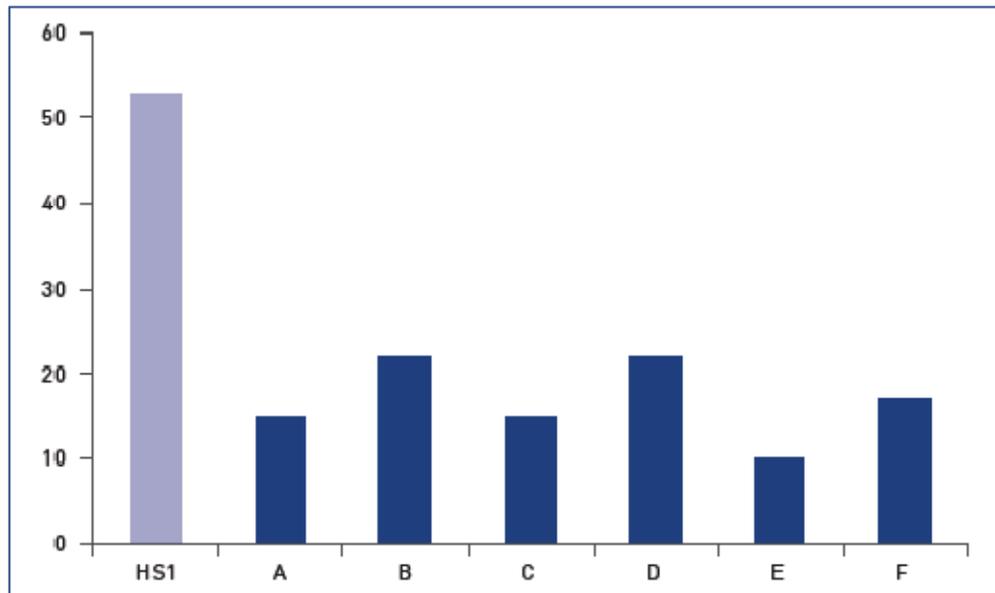


Source: Statistics Norway.

Future energy costs and the generation/supply of power will therefore have a significant impact on the economics of HSR.

The construction costs of HSR will vary for many different factors. Research by the UIC indicates that the average cost of construction of HSR in Europe is between €12 and €30m per km (approx. 100-240m NOK). This is borne out by an international benchmarking exercise carried out in the UK by HS2 Ltd. A comparison was made between construction costs of the UK’s only high-speed line, HS1, and six European comparators in France, Germany, Italy and Spain. Figure 3.5 shows the resulting cost differences, with the non-UK lines having costs similar to those reported by UIC, but UK costs being significantly higher.

**Figure 3.5 – Normalised investment costs for HSR construction in Europe
(£ million per route-km)**



Source: HS2 Cost and Risk Model, HS2 Ltd, December 2009.

While the reasons for the higher costs in the UK are not directly transferable to Norway, being a result of the necessity in the UK for major new terminal stations and approach routes, and the higher unit costs in the UK from the contractual approaches used and the lack of a consistent long-term construction programme, this example illustrates the potential for widely differing construction costs depending on local conditions. In Norway, the extent of bridge and tunnel works required may lead to costs being higher than the average.

The costs of HSR will in turn have an influence on the fares that need to be charged, although this will also be influenced by Government policy (covered under theme 5 below). HSR fares will of course impact directly on the level of demand, revenue and economic benefits from any HSR project. There is also an important interaction with costs and fares/prices of other competing modes – most of which (air, car, coach, ferry) will be more dependent than HSR on fossil fuels.

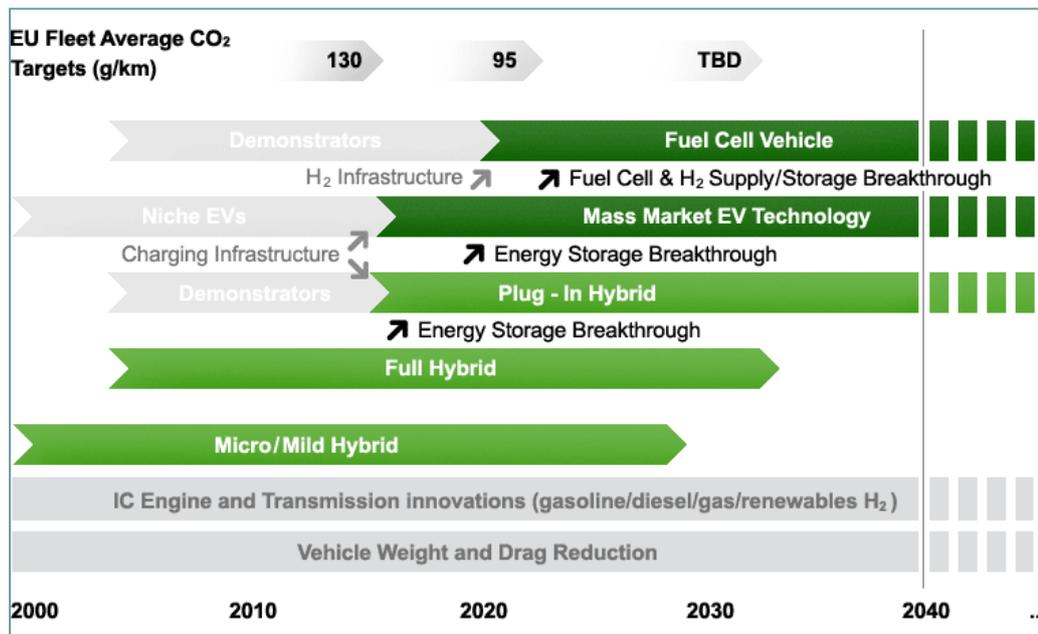
One other aspect that will have an impact on passenger demand is the relative efficiency and attractiveness of other modes compared with HSR. Future road enhancements, improvements in airport check-in procedures or the opening up of new air routes, may increase the relative attractiveness of other modes and thereby provide more competition for HSR. Other developments, such as widespread road pricing, may encourage greater travel by public transport rather than private road-based transport. These developments would also impact on HSR demand and its overall business case. Such changes have been considered and discussed in the Subject 1 report – Effects on Road and Aviation Sectors.

The National Transport Plan sets out overall policies and investment plans for the Norwegian transport sector through to 2019. Planned future rail and road improvements, including those that are assumed in the NTM-5 and new High Speed Rail demand model, are set out in the Market Analysis Subject 1 (Demand Forecasting). The current government is increasing its investment in roads and rail, but not in airports, although Avinor, the airport operator has proposals for expansions at both Bergen and Oslo Gardermoen. Several of the highway sections that will compete with HSR will be improved over the coming decades (for example, Oslo – Kristiansand, Oslo – Lillehammer, Oslo – Halden). While all transportation investments currently planned for the next ten years are described in the National Transport Plan, policies may well change in future depending on the composition of parliament. The policies of county municipal authorities

will also be influential, given their recently increased responsibilities for highways and ferry connections.

As well as infrastructure developments, vehicle technological developments will also have a significant impact on the competitiveness of the private car in the future. In terms of energy efficiency and carbon emissions, cars can be expected to become substantially more efficient in the future. As Figure 3.6 suggests, the automotive industry will continue to innovate in conventional internal combustion (IC) engine technology and to deliver ongoing reductions in vehicle weight and drag. In addition, over the next decade or so, the development and increased take-up of hybrid vehicles is expected to be accompanied first by the introduction of electric vehicles and then, when technology has developed, by fuel cell vehicles. However, the path to these future technologies is by no means clear. For plug-in electric vehicles (and electric hybrids), significant developments in battery technology will be required before such vehicles could begin to penetrate the mass market. The same applies to fuel cells.

Figure 3.6 – Roadmap for automotive development in Europe



Source: Automotive Council UK.

The impact of these types of development on the costs of car ownership and operation are unclear at this stage, but these technologies will help to mitigate the poorer carbon performance of car travel compared with public transport, and will also lessen the sector’s dependence on oil (depending on the source of electricity generation). It should be noted, however, that recent gains in energy efficiency and costs (resulting, for example, from shifts from petrol to diesel cars) have been offset by increases in vehicle weight, due to increased power requirements, greater attention to passenger comfort and features such as air conditioning. Moreover, these technological gains are unlikely to result in substantial speed improvements for private car journeys and so the car’s competitiveness with modes such as air travel or high-speed rail will continue to be limited for medium to long distance journeys.

In the aviation sector, improvements will continue to be made to air travel, although without the technological transformation that may take place in the automotive sector. Improvements can be expected in airport procedures which improve the passenger experience, and in the efficiency of aircraft operation.

Virtual check-in and security facilities may develop further, through increasing use of digital technology – 2D bar codes, new mobile applications, the internet and biometrics. This could be accompanied by mini 'virtual' airports away from the traditional airport campus, combining

parking, bag drop-off, validation of travel documents and authorisation, bypassing check-in halls and security checkpoints. The extent to which these improvements will be widely available, or restricted to premium passengers, is likely to vary depending on the size of airports (economies of scale tending to favour such developments at larger airports), the extent of airport congestion (and hence the need for moving processes off-site), and airlines' and the airport operator's competitive behaviour (the need to retain passenger dwell time in order to protect airport retail revenues).

These improvements may have an impact on passenger travel times, reducing the time needed for check-in and possibly also exit from the airport. However, in practice, the benefits to passengers will be moderated by factors such as commercial pressures on airports and airlines to maintain retail revenues and offer reliable transit times. The Subject 1 Impact on Road and Aviation Sectors report proposes testing the impact of a reduction of five and ten minutes to check-in time. This could result in a reduction of the three-hour journey time threshold at which HSR is expected to capture the majority of the air-rail mode share.

The introduction of next generation aircraft will also affect aviation economics, with airframe improvements and evolutionary engine improvements expected to be delivered over the coming years. Together with improvements to operational practices and air traffic management, it is estimated⁴ that these potential savings would mean that a new, 2025-vintage aircraft flying in an improved operating environment would be 40-50% more energy efficient than a 2006 plane flying in a 2006 operating environment. However, because of the long operating life of modern aircraft, fleet replacement takes many years, so such efficiency improvements may take a relatively long time to materialise. These aircraft improvements would reduce the costs of the aviation sector and should, in a suitably competitive environment, reduce air fares for passengers. However, there is of course an interaction with fuel prices, with these expected to increase over the long-term.

3.6 Theme 4: Construction solution and technology for HSR

International HSR experience is currently expanding rapidly and the performance and capability of HSR technology is evolving as new countries such as China develop their own expertise. According to the UIC, 14,400 km of lines are in operation across the world and 10,000 km are currently under construction. How this technology can be applied in Norway, with somewhat different climatic, topographical and geological conditions to many other countries that have built HSR lines, is another consideration. Table 4.4 sets out the major uncertainties under this theme.

Table 4.4 – HSR technology uncertainties

Uncertainty	Description
Evolving technical standards for HSR infrastructure internationally	Difficult to establish technological standards when international practice is developing rapidly. Increasing expectations and improvements in other countries may need to be matched in Norway.
Evolving technical standards for rolling stock	Difficult to establish technological standards when international practice is developing rapidly. Operating speeds, capacity, efficiency, economic life, may all change in future.

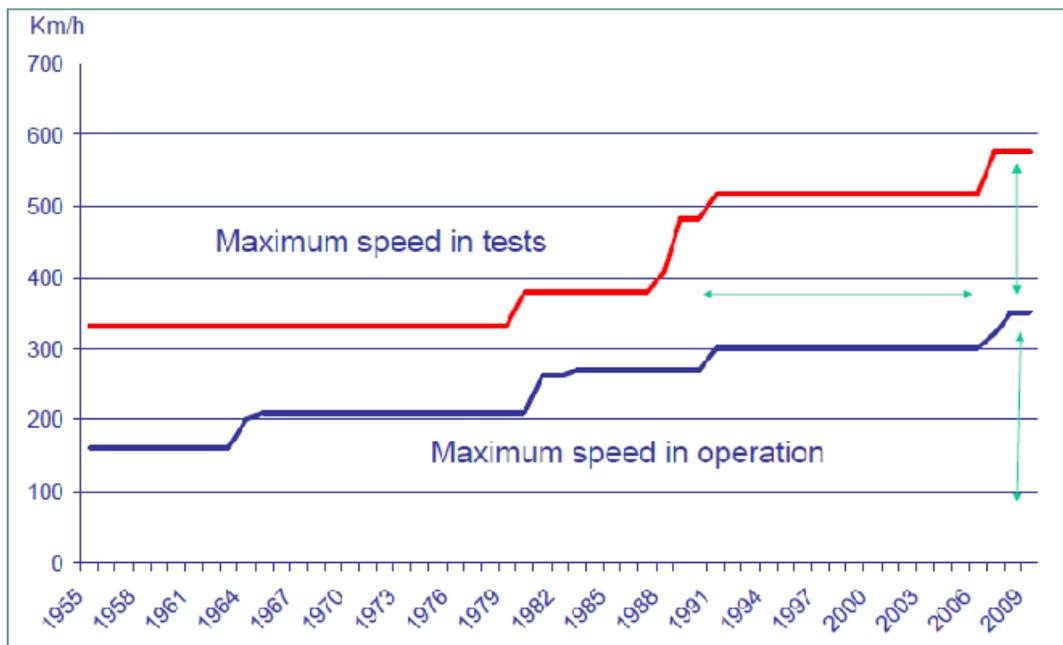
⁴ QinetiQ, for the UK Climate Change Commission

Uncertainty	Description
Safety requirements and technical standards	National or European safety requirements and technical standards may discredit Asian components and systems, or environmentally friendly or economical solutions.
Future development of HSR or conventional rail technology	HSR performance may significantly improve, with consequent service and price benefits. Maglev may become viable as an alternative to HSR. Availability of discontinuous electrification may allow a lower cost upgraded network to be developed as an alternative. Depends in part on approvals process for new technology.
Implications of Norwegian terrain on HSR carbon performance	Technical requirements of Norwegian terrain may increase carbon footprint of HSR.
Implications of Norwegian terrain on HSR safety requirements	Safety requirements may drive or constrain technical solutions e.g. obligation to have double track in tunnels, specific requirements re evacuation.
Implications of Norwegian terrain on construction solution and costs	Impact on construction costs of mountainous terrain, fjords, remote working - higher prevalence in Norway, scale of geological issues to be addressed, length of tunnels, gradients.
Implications of climate on HSR construction and operation	Impact of frozen ground conditions or cold climate on standards, safety and productivity. Reliability of HSR in Norway, particularly in winter, may be worse than expected. Risk increases with long stretches of single line. Interactions with passenger reactions/demand levels.
Rolling stock maintenance requirements	Climatic impact (e.g. de-icing) may affect how maintenance needs to be undertaken and how frequently. Winterisation requirements and their impacts on reliability and cost need consideration.
(If solution tends towards a mixed traffic line), performance implications of mixing different types of traffic	Freight, regional passenger traffic, high speed passenger – could cause a higher number of hazards/ accidents and increase risk - more complex mitigation measures may be needed.
Environmental/carbon performance of HSR	Depends on development of HSR technology and operating efficiency.
Availability of solutions to address noise and vibration or other environmental issues	Extent of solutions available to meet issues is unclear and additional costs may be incurred.

Uncertainty	Description
Impacts of climate change	More thawing, more water – more flooding and subsidence problems. New technological solutions may be required.
Supply market maturity	A still maturing supply market may lead to wrong decisions about scope or technology based on wrong prices.
Scale of international HSR development (or other similar projects in Norway)	Supply chain may not be able to match the scale of HSR development.
Swedish rail/HSR policy and technical development	Interface with Swedish routes may introduce a new set of requirements if Norwegian HSR is to be compatible.
International technical standards	If technical standards are different between countries, this could give problems using specs from overseas and linking to international networks.
Interfaces with other transport projects	Success of HSR may be dependent on other complementary rail/transport projects such as enhancing capacity in Oslo – both rail capacity and at stations.

Since HSR was first introduced in Japan in 1964, operating speeds have increased from 210 km/h to 350 km/h now achieved in China. This has been facilitated by the development of higher performance rolling stock and by infrastructure design that allows high speeds and high reliability levels to be achieved consistently. HSR technology continues to evolve in Asia and in Europe and, given the long lead times for development of HSR projects, any business case for HSR in Norway needs to ensure that it takes account of likely technology capabilities in 10-20 years time.

Figure 3.7 – Evolution of maximum speeds for HSR



Source: UIC.

The world speed record for high-speed rail was set at 575 km/h in France in 2007. Since then, a new Chinese record speed of 486 km/h was established on December 3 during trial running on a section of the Beijing – Shanghai high speed line – the fastest speed recorded by an unmodified commercial trainset. Figure 3.7 above suggests that there may be approximately a 20-year lag from a maximum speed being achieved in tests and a similar speed being achieved during normal operations.

The UIC⁵ expects future technological development in the following areas:

- Higher service speeds, with maximum speeds in the range of 320 - 360km/h and more availability time for infrastructure;
- New conception of infrastructure elements, with ballasted or unballasted track, new fastening systems, and new materials (e.g. catenary wires);
- Standardisation and modularity of rolling stock;
- New braking systems;
- More environmentally-friendly (noise, energy efficiency), with improvements on safety, security and comfort, systems to handle cross winds, typhoons and earthquake detection, etc.;
- New technologies (telecommunications, WI-FI, etc.).

In the coming years, high speed rail operators will require business concepts to deal with the following:

- More capacity (with double deck trains and/or 2+3 seating instead of 2+2);
- Greater availability and maintainability of trains (RAMS – reliability, availability, maintainability, safety);
- Further reductions in costs of procurement and maintenance (life cycle costing);
- Further reductions in fees for infrastructure use;
- More energy efficiency and less energy consumption;
- Optimisation of operating costs (i.e. during low occupancy);
- Globalisation.

The pace and scale of this technological development is unknown at this stage. Related to this is uncertainty over the extent to which the international supply chain is sufficiently well-developed to provide the most appropriate technology at competitive prices, and how this might be affected by similar projects competing for the same limited resources, either in Norway or overseas. There may also be a cost/supply risk if different standards are adopted in Norway to those used elsewhere. If for example, a solution with lower operating speeds is developed in Norway (say, 200 km/hr) it may be difficult to secure competitive bids from manufacturers for infrastructure and rolling stock if they are more focussed on developing technology for higher line speeds.

One factor that needs to be considered alongside the future performance and cost of HSR, is how this might be affected by the specific challenges of constructing and operating HSR in Norway, given the more challenging terrain and more severe climatic conditions experienced here compared with most other countries that have implemented HSR.

The mountainous terrain, especially between Oslo and Bergen, and Oslo and Trondheim, will have an impact on HSR alignment and design choices. The existing rail and road network follows the alignment of the valleys, which is not conducive to conventional (300 km/h or above) HSR

⁵ High Speed Rail – fast track to sustainable mobility, UIC, November 2010.

operating speeds as the radii of the curves will be too small. Hence, extensive tunnelling is likely to be necessary in order to achieve the necessary alignment, with significant cost consequences. For lower speed operation, such as 200 km/h, the effects would be less severe. While there are several new rail lines and highways currently being planned and built in Norway, including two major new rail lines which includes several tunnels and bridges - Oslo-Ski (at masterplan stage) and Vestfoldbanen (detailed design stage) – the design standards for these are less onerous at 250 km/h than they would be for HSR at 300 km/h and above. This issue will need to be tackled during the planning and design stages of HSR route development.

To be effective, HSR in Norway would need to interface well with other transport systems. This may include international HSR networks – particularly in Sweden if HSR is developed there – and other rail or urban transport projects in Norway. The business case for HSR may be significantly influenced by the extent to which effective through services or connections can be provided, and this is dependent on the development of other related projects.

The two potential HSR corridors in Norway that interface with Sweden are Oslo – Karlstad (for connections to Stockholm) and Oslo to Halden (for connections to Gothenburg). There are long term aspirations in Sweden for HSR development, although work is focussing on the lines Stockholm-Jönköping-Gothenburg and Stockholm-Jönköping-Helsingborg/Malmö, which don't interface directly with Norwegian HSR. The upgrade of the line Gothenburg-Malmö was commenced in the mid 1990s and is designed for speeds from 160 km/h (early parts) to 250 km/h (recent parts). Effective international connections and through services are clearly dependent on consistent technical standards and line speeds.

3.7 Theme 5: Policy and legislative background

The case for HSR development sits within wider Government policy on transport, energy, land use planning, environment and other factors – and this may change in the future as governments change and public opinion shifts over time. Table 5.5 sets out the major uncertainties under this theme.

Table 5.5 – Policy and legislative uncertainties

Uncertainty	Description
Government policy on transport and/or HSR	<p>Overall policy on different transport modes (e.g. supporting HSR or aviation) may change over time, particularly because of long delivery period for HSR.</p> <p>Risk of policy decisions favouring competing schemes and undermining HSR demand – at local, regional or national level.</p> <p>Policy on fares for rail, HSR and other transport modes may change in future.</p> <p>New demand management policies such as road pricing may be implemented.</p> <p>Policy views are dependent in part on assessments of carbon impacts of HSR (and rail in general).</p>
Changes in policies or legislation during HSR development and construction	Changes in policies or legislation during development and construction period may change scope, costs and benefits of HSR.

Uncertainty	Description
Delivery of related international or domestic projects	<p>Swedish HSR plans may change and develop faster or slower than those in Norway.</p> <p>Domestic aviation policy – airport development, support to regional routes – may change.</p> <p>Complementary local/regional transport projects in Norway may change.</p> <p>New urban development areas/projects which affect population in relevant cities.</p>
Government policy on environment and climate change	<p>Designation of new protected areas (such as water conservation areas, nature reserves).</p> <p>Tougher environmental protection requirements.</p> <p>Policies on carbon pricing.</p>
Government policy on energy	<p>Power supply and generation policy will affect carbon performance of HSR and cost of operation.</p>
Government policy and legislation on planning	<p>Planning processes and requirements to secure project authorisation may change or legal responsibilities for planning application(s).</p> <p>Standard processes may need to be adapted for HSR, with consequential lack of clarity over requirements.</p> <p>Risk of inconsistent decision-making at different levels of institution and additional requirements (e.g. additional station stops) that affect business case.</p> <p>Future changes in local policy background may lead to different requirements for or constraints on HSR.</p> <p>Risk of plans for land use that would deliver demand not subsequently being implemented.</p>
Government policy or legislation on project financing and structuring	<p>Current policy is to finance road and rail projects with public financing – any change to policy, or to yearly budget constraints, may require HSR project structuring and financing strategy to change mid-project. (This is mitigated to a degree by the current review of alternative models under the Commercial and Contract Strategies Contract.)</p> <p>Varying objectives of funders/financiers may lead to conditions being attached – on public sector or private sector financing.</p>
Safety standards and/or legislation	<p>Change in standards may require additional protection.</p> <p>High demands may be made by safety authorities that are difficult to challenge.</p>
HSR security provisions	<p>Security provisions similar to airports may be required for HSR leading to less mode shift.</p>
Government policy on labour and employment	<p>Change in policy could affect cost and availability of labour for construction or operation. e.g. immigration laws preventing use of foreign contractors from outside EEA.</p> <p>Any future membership of EU could affect policies.</p>

The table above demonstrates that there are many areas of public policy that will impact on the case for HSR, both in terms of its strategic case (HSR's place in a sustainable transport system) and on its business case (such as land use development supporting high-density development around HSR stations). At the current time, the Norwegian Government and Congress are not unanimously in favour of HSR, which means there is a policy risk around any development of HSR. This may be mitigated when a final decision on HSR implementation is made through a parliamentary binding agreement.

3.8 Conclusions

Many of the uncertainties listed in this chapter, even if their potential impacts are substantial, can be treated as project risks that need to be managed by any HSR promoter or developer. Other uncertainties would have a more fundamental effect on the case for HSR and so require further consideration. The key uncertainties with more wide-ranging effects, most of which have interactions with other factors, include:

- The pattern and rate of future economic activity and how this affects the nature of the demand for travel;
- Public and political priorities on environmental issues and how this affects the appetite for HSR development in Norway and the propensity to use HSR services in the future;
- The future cost and security of supply of energy – both oil and electricity;
- Government policy and commercial or technological developments in competing transport modes, in particular the aviation sector (mode shift from air being expected to be the driver of carbon savings).

4 Recommendations for the treatment of uncertainty

4.1 Introduction

This Chapter puts forward recommendations for addressing the key uncertainties during the decision-making process, through the use of QRA, reference class forecasting, sensitivity tests or scenario planning. The economic and financial assessments of HSR (and non-HSR) options need to be able to demonstrate the possible impact of the major uncertainties on the key decision-making criteria and on the case for HSR.

4.2 Treatment of major uncertainties

4.2.1 Demographic and economic factors

The uncertainties under Theme 1 all affect the demand, revenue and economic benefits of HSR. Factors that can be considered in relative isolation – such as population growth – could be assessed through sensitivity tests, by altering forecast rates of growth. However, most other factors have more complex or interacting effects and are likely to be best assessed through scenario planning techniques. In this way, plausible future scenarios would be developed that incorporate a set of plausible assumptions on:

- The rate and pattern of economic growth, including whether growth rates and consumption continues at historic patterns or whether a shift might occur due to changes in perspective and priorities (such as environmental concerns);
- Patterns of travel demand, for business and leisure travellers, and how these might be affected by shifts in attitudes and/or communications technology.

4.2.2 Human factors

Public reactions to the development of HSR are best handled as project risks, as they are likely to have impacts on project costs and/or timescales and should be managed or at least monitored by the project promoter. In practice, this means making a suitable provision in QRA or ensuring that optimism bias adjustments cover such impacts.

The effect of shifting passenger perceptions of HSR and the subsequent impacts on demand and revenue can be assessed through sensitivity tests, by applying different factors to represent the attractiveness of HSR, or by changing mode choice parameters. There is some interaction with the factors under Theme 1 that affect travel demand patterns, particularly environmental perceptions, so some impacts will also be considered under scenario planning processes.

4.2.3 Costs of HSR and other modes

Some HSR cost factors can be considered straightforwardly as project risks that need to be included in a QRA or optimism bias adjustment. These are the costs that have little interaction with other uncertainties:

- Exchange rates or interest rates;
- Construction sector price inflation;
- Costs of raw materials;
- Future salary/wage costs.

The cost and security of supply of oil and electricity have more complex effects, not just on HSR costs but on the costs of competing and complementary modes of transport and hence on transport prices too. Future scenarios that consider these impacts would be the most effective way of assessing these uncertainties, although they should also be included in QRA.

Other uncertainties that affect the demand for HSR but that can be considered in isolation, through individual sensitivity tests, include:

- Policy on transport prices for HSR and other modes;
- Developments in the aviation sector that affect the attractiveness, cost and environmental performance of air travel;
- Developments in the road sector that affect the attractiveness cost and environmental performance of car or coach travel.

4.2.4 Construction solution and technology for HSR

Most of the uncertainties under Theme 4 represent project risks that can be reflected either explicitly in the QRA or implicitly through optimism bias adjustments. These factors are those whose main impacts are on project costs, including:

- The implications of Norwegian terrain and climate;
- The impacts of climate change on HSR;
- The capability of the supply chain to deliver;
- Compatibility with international technical standards.

The exceptions are the factors that also affect HSR performance, such as future developments in HSR technology for infrastructure and rolling stock, and interfaces with other complementary transport projects. It would be more appropriate to carry out sensitivity tests for these factors, in order to understand the implications on costs and benefits of, for example, substantially improved operating speeds. The impacts of climate change may include, as well as an increase in HSR construction costs, an increase in electricity prices (from increased demands for heating, for example) together with impacts on passenger demand. A sensitivity test could therefore be carried out, in addition to inclusion in the QRA, to assess these effects.

4.2.5 Policy and legislative background

Similarly, some of the policy uncertainties under Theme 5 are project risks, which will impact on costs and/or timescales and so should be reflected in QRA and/or optimism bias adjustments as appropriate. These include:

- Policy on environmental protection;
- Policy and legislation on planning;
- Safety standards and/or legislation;
- Policy on labour and employment.

Sensitivity testing can be used for certain other factors, such as security requirements and policy on project financing. The uncertainties on policy on other transport modes overlap with those under Theme 3 and so their effects can be assessed through the same sensitivity tests.

Other uncertainties – overall policy on transport and on different modes, together with policy on energy – are best considered through the scenario planning process, as their impacts are complex and interacting.

4.2.6 Summary of recommendations

This Chapter has shown that the potential impacts of the major uncertainties and risks can be assessed through the tools available: QRA, optimism bias adjustments, sensitivity tests and scenario planning. The QRA and optimism bias processes are discussed more fully in the Subject 2 Cost Estimation report and the Subject 4 Economic Analysis report. The scenario planning process is described below.

It is recommended that the set of sensitivity tests to be carried out in Phase 3 of the project includes:

- Rate of population growth;
- Rate of economic growth;
- Passenger perceptions on the attractiveness of HSR;
- Passenger mode choice behaviour;
- Transport prices (or fares) for HSR and other modes of transport;
- The cost and attractiveness of air travel;
- The cost and attractiveness of car travel;
- Enhanced performance of HSR, including operating speed, reliability, capacity, cost;
- Impacts of climate change on HSR construction and operation;
- The impact of key complementary transport projects.

4.3 Scenario planning

Section 4.2 has highlighted that the major uncertainties that require scenario planning analysis to consider their full range of effects on the case for HSR are:

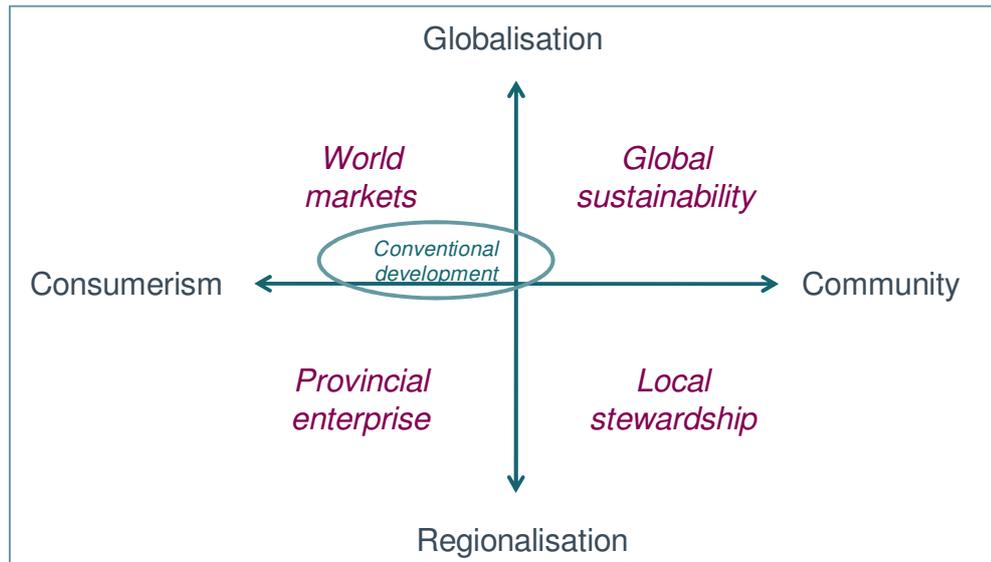
- The rate and pattern of economic growth;
- Patterns of travel demand, and how these might be affected by shifts in attitudes and/or communications technology;
- The cost and security of supply of oil and electricity;
- Public policy on transport development and energy.

As discussed earlier, scenarios should be developed considering the key drivers of future change and allow critical uncertainties to be distinguished. They should also be credible and internally consistent. Previous HSR studies carried out by Atkins have used a set of scenarios developed under the Foresight programme that consider two axes of change:

- Governance scenarios – either globalisation or local/regionalisation;
- Social values – either individual/consumerist or community-focused.

Figure 4.1 sets out the resulting four scenarios, together with an indication of where conventional development would lie on these axes. These would allow consideration of the key uncertainties identified above, as long as a greater focus on sustainability vs consumption issues was applied to the second (horizontal) axis. This approach is similar to one recently put forward in the UK by Network Rail.

Figure 4.1 – Foresight scenarios



Source: The Strategy Unit, UK.

The key characteristics of the scenarios would be:

- **World markets.** Places an emphasis on short-term welfare, and meeting personal consumption demand, supported by strong global institutions, especially those promoting and governing trade. Little focus on environmental sustainability. It has the following features:
 - High GDP growth;
 - Increased population and employment, with inward migration;
 - Low energy prices;
 - High levels of transport investment;
 - Market-driven technology development in car and air modes;
 - Increased rail fares.
- **Provincial enterprise.** Also places an emphasis on the short-term and meeting personal consumption demand, but with national and provincial government being more successful in asserting their own interests. It has the following features:
 - Low(ish) GDP growth;
 - Levels of population and employment similar to current forecasts;
 - Increases in energy prices;
 - Car dependency;
 - Little investment in transport infrastructure;
 - Increased rail fares;
 - Road pricing;
- **Global sustainability.** Places an emphasis on long term sustainability and meeting the collective needs and wants, with a globalisation of governance systems. It has the following features:
 - Medium levels of GDP growth;
 - Moderate increases in energy prices

- Investment in integrated transport;
- Technology gains in public transport modes;
- No change in rail fares;
- National road pricing.
- **Local stewardship.** Places an emphasis on the long-term economic and environmental sustainability, together with meeting collective wants and needs, but with discrete federal political systems, with sovereignty retained at national and regional levels. It has the following features:
 - Low GDP growth;
 - Decreased levels of population and employment;
 - Little transport infrastructure investment;
 - High energy prices;
 - Travel needs avoided;
 - Road pricing managed locally.

These scenarios enable the complex interactions of travel behaviour, costs of different transport modes, environmental impacts and travel pricing to be assessed. The development of assumptions for these scenarios and examination of each of their impacts will allow an understanding of the key factors that will influence the case for HSR in Norway. These scenarios could be developed and tested as part of Phase 3 of the Norwegian High Speed Rail Assessment project to determine the impact on decision making criteria.

4.4 Conclusions

A combination of all the tools described in Chapter 2 will be needed if proper consideration is to be given to all of the uncertainties identified in Chapter 3. Those uncertainties that have isolated impacts on costs or timescales, and whose impact can be estimated, should be addressed through QRA or through the use of reference class forecasting. Handling risks that affect demand or benefits is more usually complex and, even if the effects of the uncertainties can be isolated, normally a sensitivity test requiring a run of the demand and economic models will be required.

A number of major uncertainties have been identified which have complex effects on costs and benefits or that interact with other factors. These are best addressed through scenario planning techniques, and a set of future scenarios has been proposed here for future analysis.

5 Conclusions

5.1 Key Uncertainties

Five themes of uncertainty have been identified for the Norway HSR project:

1. Demographic and economic factors – the rate and pattern of future population, employment and economic activity, and its impact on travel patterns;
2. Human factors – how the public might react to HSR development and the perceptions and reactions of potential HSR passengers to a new transport product;
3. Cost factors – the costs of constructing, operating and maintaining an HSR system, and the costs of competing modes of transport;
4. Technology factors – the future development of HSR technology and that of the aviation and automotive sectors;
5. Policy and legislative factors – future changes in Government (national or local) policy on a range of areas, including transport, environment, energy, employment, planning and finance.

Under each of these themes, the major uncertainties have been identified and the potential impacts on HSR development have been described.

5.2 Recommendations

Four tools have been identified for supporting decision-making in the face of risk and uncertainty:

- Quantified risk assessment;
- Reference class forecasting;
- Sensitivity testing;
- Scenario planning.

These tools are suitable for addressing different types of uncertainty and it is recommended that in Phase 3 of the Norway HSR project, the following assessments are carried out.

Quantified risk assessment should include consideration of the following risks:

- Public reactions to environmental effects from construction of a new route;
- Public reactions to public funding required for HSR;
- Changes in exchange rates or interest rates;
- Construction sector price inflation;
- Costs of electricity and/or oil;
- Change in costs of raw materials;
- Changes in future salary/wage costs and public policy on labour and employment;
- Impacts of safety requirements and technical standards;
- Implications of Norwegian terrain and climate on HSR performance, safety requirements or costs;
- Cost and availability of solutions to environmental issues or policy changes;

- Impacts of climate change;
- Supply market maturity and capability;
- Interface with possible future Swedish HSR routes;
- Differences in international technical standards;
- Changes in public planning policy and processes.

In addition to QRA, it is likely to be appropriate to consider optimism bias adjustments (reference class forecasting) on certain cost categories where there is less certainty over costs or where there is a known tendency to underestimate costs. Optimism bias will be added in a sensitivity test of the economic analysis of each of the options.

For uncertainties that affect demand and benefits as well as costs, sensitivity tests are likely to be required. The set of sensitivity tests to be carried out in Phase 3 is recommended to include the following:

- Rate of population growth;
- Rate of economic growth;
- Passenger perceptions on the attractiveness of HSR;
- Passenger mode choice behaviour;
- Transport prices (or fares) for HSR and other modes of transport;
- The cost and attractiveness of air travel;
- The cost and attractiveness of car travel;
- Enhanced performance of HSR, including operating speed, reliability, capacity, cost;
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- The impact of key complementary transport projects.

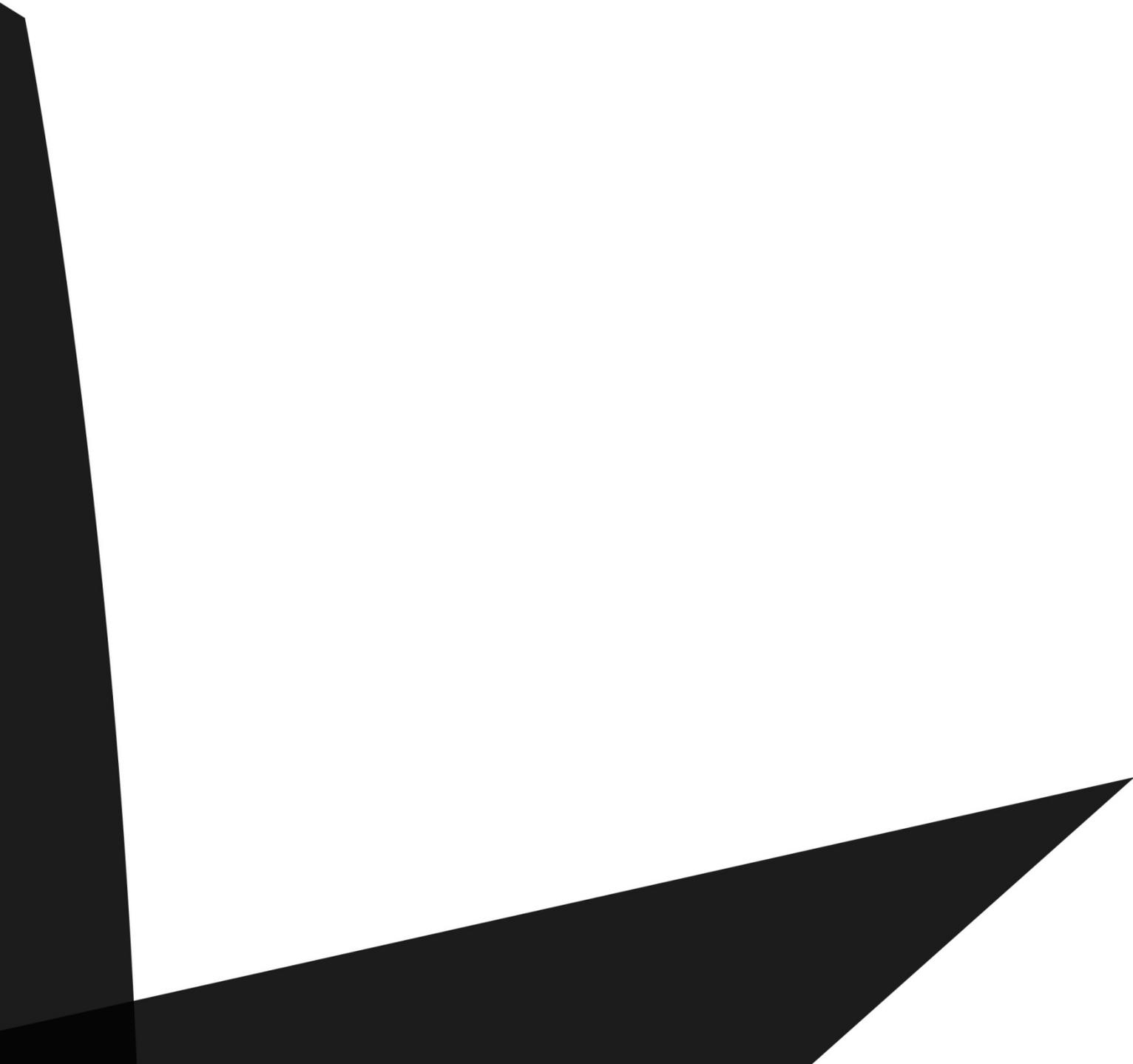
Finally, a scenario planning approach can assess the implications and interactions of the following uncertainties:

- The rate and pattern of economic growth;
- Patterns of travel demand, and how these might be affected by shifts in attitudes and/or communications technology;
- The cost and security of supply of oil and electricity;
- Public policy on transport development and energy.

Four future scenarios are proposed for future development in Phase 3, covering different aspects of globalisation/regionalisation and consumerism/sustainability.

5.3 Next steps

Phase 3 of the study should encompass the risk assessments, sensitivity testing and scenario planning exercises described above, in order to present a full picture of the potential case for the development of HSR in Norway. If a decision is made to proceed with the project, it will be important to monitor and manage the key risks and uncertainties on an ongoing basis. This can be done through effective management of the project risk register, as long as this is sufficiently comprehensive to include the wider uncertainties discussed in this report as well as specific project risks. Management of risks and uncertainties may include acceptance (and monitoring of risks), mitigation of impacts or transfer to other parties.



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