International Transport Forum

Strategic Infrastructure Planning

International Best Practice

Case-Specific Policy Analysis

OECD

NATIONAL INFRASTRUCTURE COMMISSION

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The International Transport Forum

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Case-Specific Policy Analysis Reports

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Foreword

Discussions at the OECD frequently consider infrastructure investment as a means of stimulating economic activity, addressing regional variations in productivity, and delivering mobile and inclusive societies. Sound modern infrastructure allows economies both to reap the benefits of globalisation, and to ensure those benefits are shared among people and places.

Planning of infrastructure is essential, but those plans can't be set in stone. The long life and high cost nature of infrastructure requires a broad and long-term view at a national level: infrastructure has to anticipate demographic and social change, and be farsighted enough to capitalise on the benefits of future technological advances. Uncertainties around the future mean that investment plans must contain flexibility, but at the same time still retain enough clarity in their strategic aims. The National Infrastructure Commission has been set up precisely to provide the Government with impartial, expert advice on major long-term infrastructure challenges.

Britain has often been at the forefront of infrastructure development in the past: roads, canals and railways all played their part in earlier industrial revolutions in the UK. In the more recent past, Garden Cities and New Towns took fresh approaches to urban planning and development. Currently, public investment to roll out high-speed broadband in the UK, including ultrafast future technologies of full fibre and 5G, anticipates the communication infrastructure needs of the future.

Organisations like the ITF, which is part of the OECD family, allow members to share our experiences and approaches, to learn from one another's good practices, and to share lessons from the past. This project by the ITF, and the meeting in London in June 2016, allowed UK experts to hear about experiences in other countries including Australia, Denmark, France and Japan, but also to hear the private sector perspective on infrastructure planning, and consider energy and transport sectors.

I am grateful to ITF colleagues, and to all involved, for their efforts to support the UK as the National Infrastructure Commission proceeds with its work, and look forward to continuing these discussions in the future. I hope the insights contained within this report can be of use not only for the UK, but also for other OECD members considering the same challenges.

Christopher Sharrock
UK Ambassador to the OECD

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The UK National Infrastructure Commission asked the International Transport Forum (ITF) at the Organisation for Economic Co-operation and Development (OECD) to identify global best practices in strategic infrastructure planning and explore how selected OECD member countries deal with planning challenges. This report summarises a discussion of experience in strategic planning between experts and decision-makers at an expert meeting convened for the NIC by the ITF. The meeting took place in London at the FIA Foundation on 13-14 June 2016.

The project was directed by Jagoda Egeland. The report was written by Jagoda Egeland and Stephen Perkins (ITF), with contributions from Adrian Dwyer (Executive Director – Policy and Research, Infrastructure Australia), Yves Crozet (Professor, Lyon University), Henk Krijnen (Managing Partner, NavIncerta), Katsuhiro Yamaguchi (Visiting Researcher, Graduate School of Public Policy, University of Tokyo), as well as the expert meeting participants (see Annex II).Valuable comments on a draft version of the report were provided by Alex Chirmiciu (EBRD), Adam Cooper (National Infrastructure Commission), Francesca Fabbri (National Infrastructure Commission), Liv Gudmundson (ITF), Jim Hall (University of Oxford), Dejan Makovsek (ITF), Mark Ledbury (UK Department for Transport), James Richardson (National Infrastructure Commission), Bridget Rosewell (National Infrastructure Commission), Jesse Shuster-Leibner (ITF) and Nathan Zhivov (ITF).

Table of contents

Executive summary 9

Defining the infrastructure planning challenge 15

The challenge of creating a long-term planning framework that can respond to change 15

The challenge of creating independent, credible planning institutions while fostering political commitment 16

Government infrastructure investment planning: Objectives 19

Defining the need for infrastructure investment 19

Planning objectives in the United Kingdom 21

Planning objectives in other OECD countries 22

Government infrastructure investment planning: Process and methodology 25

United Kingdom 25

Infrastructure Australia 26

Electricity planning in France and Europe 29

Transport infrastructure planning in France: From sectoral master plans to planning for multimodal mobility and the energy transition 35

Strategic regional cross-sectoral planning: The Oresund Fixed Link between Sweden and Denmark 43

Infrastructure planning in Japan 45

Strategic infrastructure planning: Account for uncertainties and interdependencies 49

Stakeholder engagement 49

Addressing uncertainty through scenario-based planning 51

References 55

Annex I. Uncertainty analysis for long-term decision making 58

1. Definitions 58

2. Probabilistic valuation 61

3. Risk management integration 63

4. The use of scenario thinking 65

5. Integration and decision making 74

References 75

Annex II. List of expert meeting participants 76

Notes 80

Executive summary

Background

Providing stable long-term direction to infrastructure investment whilst retaining the flexibility needed to deal with uncertainty over long horizons is a challenge for governments. To address this issue, the UK established a National Infrastructure Commission (NIC) in 2015 to develop a strategic framework for planning major investments beyond the timeframe of electoral cycles.

How planning frameworks in other countries have been addressing this challenge can provide useful benchmarks for progress in the UK. The NIC asked the International Transport Forum (ITF) at the OECD to identify global best practices in strategic infrastructure planning and explore how selected OECD member countries deal with planning challenges. In particular, the NIC's interest was for the ITF to examine how to incorporate uncertainty into decision-making frameworks, account for interdependencies across different sectors of economic infrastructure, and structure the process to bring stakeholders on-board. The focus was on the transport and energy sectors.

This report reviews the experience with strategic infrastructure planning in a selection of countries and complements that analysis with a discussion of how strategic planning is conducted in the private sector. It summarises the discussion of a roundtable organised by ITF which brought together 27 international experts in London in June 2016. The roundtable was organised around presentations from regulators, policy makers and researchers on the strengths and weaknesses of strategic planning approaches in Australia, Denmark, France and Japan as well as reviews of planning practice from international financing institutions such as the European Bank of Reconstruction and Development (EBRD), Global Infrastructure Hub, International Monetary Fund (IMF) and the World Bank.

Findings

Infrastructure planning strategies in the transport and energy sectors of the countries reviewed share some high-level similarities. Most rely on bottom-up, project-by-project assessment of costs and benefits. The use of a top-down approach to developing infrastructure plans is relatively uncommon. Planning strategies are predominantly based on estimates of national population and economic growth rates rather than on detailed assessments of the location of population and economic growth. Many strategies also rely on scenario-based approaches to consider different possible outcomes. Also, stakeholder consultation usually forms part of the process.

Strategic master plans for the development of infrastructure by sector provide a valuable framework for extension of networks in France and Japan. These master plans have created a degree of consistency over time that has minimised planning and political risk and facilitated funding and financing. For example, master plans gave direction to the development of motorways (under tolled concessions) and high-speed railways in both countries. In France, they also drove integrated regional planning and electricity transmission; and cross-border electricity network integration at the European scale. Australia in contrast has a tradition of project-based planning without sectoral master plans. The UK lies between these approaches. It uses medium-term sectoral plans for strategic highways and rail network control periods, but without the long-term focus that was characteristic of master plans in France. Both Australia

and the UK are now developing a more comprehensive, long-term strategic approach to infrastructure development. In Australia, the creation of an independent planning body, Infrastructure Australia, was welcomed by stakeholders and has secured more bi-partisan support for project priorities. It also added greater transparency and visibility to the process of project selection and prioritisation. Infrastructure Australia has also encouraged a greater focus on cost-benefit analysis as a basis for decision making and an Infrastructure Priority List has been created to guide decision makers. A focus on policy and reform, in addition to project appraisal and prioritisation, has added depth and credibility to the organisation. This has allowed it to avoid the perception of delivering a simplistic pipeline of projects.

The limits to the master plan approach in France and Japan have been exposed by financial crises against a background of maturing networks with declining rates of return on investment at the margin. Fiscal constraints have led France to reprioritise projects on the basis of the internal rate of return. This has seen road projects brought to the fore after more than a decade of priority to rail investment.

The Grand Paris Express metro project has escaped this trend because of the strong cross-party support built through stakeholder consultation. This underlines the importance of consultation in achieving stable planning frameworks, but also reflects the danger of creating coalitions around projects that potentially serve purely local rather than national interests. Sweden's planning experience similarly underlines the importance of building cross-party support and highlights the role of independent commissions in creating the political space for consensus to be achieved. Together, they can potentially liberate the process from the short-term stresses of elections and leadership challenges.

In Japan, as in France, the response to diminishing returns on investment in new high-speed rail lines in peripheral areas was to remove responsibility for financing such lines from the commercially viable parts of the high-speed network. The government is funding extensions to high-speed lines in a number of such areas to stimulate tourism through related investment in hotels. Decisions are based on considerations of regional equity, not direct economic returns.

The replacement of sub-sectoral transport master plans with a multimodal approach is the other major development in French strategic planning. Again, this is reflected in Japan. Attention to multimodal interchanges and interconnections and to the impact of, for example, rail projects on the road network, has long been part of planning, but the new emphasis is on value-for-money in projects across transport modes. This is accompanied by a focus on bottlenecks (notably in deficiencies in port hinterland infrastructure in the north of France), congested rail links, and congested roads. These developments echo the recommendations from the 2006 Eddington UK Transport Study.

France serves as a good example of how a strong tradition of national long-term planning for electricity generation, distribution, and transmission has evolved to integrate the market-led policies adopted at the European Union (EU) level. In 1946 France adopted a national planning system that guided economic development to 1992. Reconstruction and renovation of thermal electric and hydroelectric plants was a fundamental part of this plan.

The Energy Transition Law and other EU sustainability targets introduced in France have created additional uncertainties for investment in the electricity sector. In particular, the issues relating to security of energy supply might be exacerbated by the cap on nuclear power generation. Moreover, the dependence of renewable energy generation on regulatory arrangements for buying power at a guaranteed price makes regulatory risk the key factor in determining investment decisions. These considerations are very important in both France and the UK.

For economic assessment of infrastructure projects, scenarios are increasingly used in the countries examined to test the sensitivity of projects to different trends in underlying economic growth with a view

to favouring more resilient projects. This does not rule out projects with negative net present value, as a recent decision to bring abandoned rail lines back into service in the French Pyrenees demonstrates. However, it does help establish clarity in the rationale for the bulk of projects selected. For example, the explicit objective of the Japanese high-speed line extensions is to support regional employment even though it comes at a net cost to the national budget. Rather than seeking to identify potential additional benefits, this has the merit of transparency.

For some projects, the productivity effects of improved access to labour markets and agglomeration, made possible by transport investments, may be important. In Sweden and Denmark, investment in the Oresund fixed link coupled with significant public investments in universities and science parks, and in coordination with investment in other transport infrastructure achieved such impacts through integrating labour markets. But these benefits need to be identified at a detailed level on a case-by-case basis where they are thought to be significant, as the French General Commissariat for Investment points out in its critical review of the Grand Paris Express project. This line is echoed by the UK Department for Transport guidance.

For mature infrastructure networks, strategic investment planning needs to focus on value to the nation via three routes: unlocking bottlenecks that constrain growth or limit socio-economic welfare by creating rents; increasing productivity through wider economic benefits; and investing to promote the viability of local communities in more peripheral regions. In all three respects the continuity provided by long-term strategic plans built on broad consensus through stakeholder consultation will reduce risk and promote investment in the economic activities that infrastructure is designed to support.

Policy Insights

Systemic risks can be reduced where projects form part of a broad and long-term strategic plan.

Governments have a critical role in providing the framework for investment in the transport, energy, and water infrastructure on which the economy depends. Very long asset lives and large sunk costs make infrastructure investments particularly subject to risk and uncertainty.

Strategic infrastructure planning nevertheless carries its own risks.

Technology is changing the demand- and supply-side considerations more rapidly than ever before and the financial crisis underlines the scale of risk on the demand side. Plans can create rigidity and hinder the flexibility needed to respond to change. National strategic planning systems can also be subject to misuse by coalitions of stakeholders that promote projects of little overall economic value, but support each other's projects to benefit predominantly short-term or local interests.

When it works well, strategic planning can set out a stable set of priorities for future investment with durable cross-party support.

This facilitates decision-making on specific investments and has the potential to reduce planning delays. Although no plan can circumvent the hard work of engagement with stakeholders or the difficulties of trading-off national economic benefits with environmental and other costs that may fall on local communities, strategic planning can help anticipate, confront, and temper such issues.

A successful infrastructure planning process balances a stable framework with maintaining flexibility.

Creating a successful infrastructure planning process is a fine balancing act between creating a stable framework to encourage investment and maintaining planning flexibility to meet the demands of

an uncertain future. The examples discussed during the roundtable discussions shed light on what constitutes best practice.

The planning process requires clear objectives, a degree of independence and an open, collaborative approach.

An infrastructure investment planning process needs to be, firstly, anchored in clearly defined objectives, which cannot be too narrow. Secondly, it needs to be independent, but cannot be too removed from political decision-making. Thirdly, the process should be open and collaborative – stakeholder engagement needs to start at the outset of the process and stakeholders' views need to form part of the evidence base.

The planning methodology needs to address risks and uncertainties, take into account binding policy constraints and include considerations of pricing the use of infrastructure.

Methodologically, planning must address risks and uncertainties both in the assessment of the need for future infrastructure and in project selection. This is to ensure the selected projects are as robust as possible and to maximise their financeability. It must also reflect binding policy constraints, such as existing and projected future climate change agreements. Finally, considerations of pricing infrastructure use must be included, both for the purpose of general use (e.g. user fees) and for the purpose of demand management as an alternative to expanding supply.

A top-down approach to infrastructure planning to complement traditional project by project assessment is essential to a strategic assessment of long-term economic infrastructure needs across sectors.

A top-down approach maintains the focus on policy objectives rather than projects and helps form a strategic view on where investments are most pressing. However, such processes are not immune to capture from vested interests in projects of marginal value at the national level. Periodic updating and restatement of objectives may counter this risk. Long-term plans may also be overtaken by regulatory or technological change that alters patterns of supply or demand or by evidence of declining returns on investment at the margin. Strategic planning must also be informed by the results of bottom up assessments of specific infrastructure projects.

Infrastructure planning across sectors can help identify the most important systemic risks early.

Planning across sectors can help policy makers recognise the resilience implications for the entire infrastructure network. It can also provide policy makers with more clarity on where to find efficiency opportunities in the network.

Using analytical methods such as a scenario-based approach to analysis can be helpful in future-proofing infrastructure plans.

Scenarios can be used to test the flexibility of potential projects in different states of the world. Scenarios shed light on what factors would have to materialise for a project to become a success. They can complement a top-down approach to planning by providing insight into different alternatives of how to deal with important future constraints to infrastructure investment – including financeability, public acceptance, and sustainability. Scenarios can also help the policy maker develop a list of alternative options for investment depending on the future state of the economy. Such an approach moves policy making away from looking for an optimal solution (i.e. a solution maximising welfare in one future or a central-case scenario) to a new territory of looking for a robust solution (i.e. a solution that is most likely to perform well under different states of the world).

It is important to consider how demand for scarce infrastructure can be managed.

In a fiscally constrained environment, it is important for decision-makers to consider how demand for scarce infrastructure can be efficiently managed. Debt management needs to be part of any strategic investment plan.

A top-down approach could foster the development of an analytical framework for investment decisions reflecting both demand and supply side considerations

A top-down approach may be a promising avenue for developing a framework for analysis that includes both demand and supply side considerations, and weighs all socio-economic impacts against one another. A stronger evidence base, however, is needed to shed light on how to blend the top-down and bottom-up approaches in order to improve national long-term planning.

Defining the infrastructure planning challenge

Major infrastructure investments are often contentious and controversial. On the one hand, risks and uncertainties, particularly in relation to the assessment of future needs, make the decision-making process difficult. The point is amply illustrated by the fiscal consequences of the 2007/8 financial crisis. Many risks and uncertainties are magnified by rapidly advancing technological and societal change and imply that infrastructure plans need to be flexible. The level of flexibility is however limited due to infrastructure investment being irreversible and infrastructure assets being immovable. On the other hand, because infrastructure takes a very long time to deliver, infrastructure plans need to provide investment stability to ensure project success.

The discussion at the expert meeting convened for the NIC by the ITF in June 2016 revealed that one of the biggest challenges to infrastructure planning is how to balance the long-term planning certainty with the flexibility of infrastructure to respond to changes in external conditions.[1] In fact, some experts invited to the event argued that caution is needed to avoid making the system too flexible. Flexibility is important, but it can inhibit investment in infrastructure and innovation if the framework is based too much on a "wait and see" approach to regulating infrastructure.

The participants also agreed that a credible institutional architecture to support planning efforts is just as important as the plan itself. Here the challenge is that successful infrastructure planning needs both independent and transparent planning institutions as well as political courage and commitment to make infrastructure planning decisions.

The challenge of creating a long-term planning framework that can respond to change

The infrastructure planning challenge is often defined in terms of the shortfall in global infrastructure investment or the so-called infrastructure gap. This infrastructure gap is currently estimated by the World Economic Forum to amount to about USD 1 trillion per year between 2010 and 2030 globally (WEF, 2014). While the size of the gap commands attention to the challenges of infrastructure planning, the experts convened by the ITF noted that such framing of the debate may not be very helpful. The infrastructure gap only reflects the scale of the latent investment demand. It does not distinguish between productive and wasted investment or relate to what outcomes countries would like to accomplish through infrastructure provision. The infrastructure gap was closely related to the predict-and-provide approach to infrastructure planning. This approach is now obsolete, as most countries have stopped facing rapidly rising consistent levels of economic growth and face new challenges, such as managing emissions in order to improve climate change outcomes.

The experts agreed that a key challenge to infrastructure planning is incorporating different demand- and supply-side considerations into the decision-making framework. The emphasis since late 1990s has shifted to a value-for-money, outcome orientation, and to trading-off costs and benefits. A particularly important aspect of decision making is how to incorporate different demand management measures into infrastructure investment considerations. For example, managing road traffic through road user charging could be a potential solution to capacity problems on the road network.

The challenge of creating independent, credible planning institutions while fostering political commitment

The participants agreed that a credible institutional architecture to support planning efforts is just as important as the plan itself. The challenge of the governance framework for planning is that both independent and transparent planning institutions are needed as well as political commitment to infrastructure planning decisions. These two elements of a successful planning framework are not mutually exclusive and both are essential to creating a stable environment for infrastructure investment.

In a study discussed during the event, the IMF finds the UK has a strong regulatory framework for infrastructure investment, indicated by its Public Investment Management Assessment (PIMA) index (IMF, 2016). A discussion of the latest PIMA results[2] revealed that the UK has very strong public investment management institutions. Procedures for managing investment and project delivery, however, were found to be an area of relative weakness by the IMF.

One reason for underinvestment in infrastructure in the UK appears to be an insufficiently stable investment environment. Participants agreed that policy uncertainty in the UK is probably much greater than in the other countries examined, especially when it comes to large projects. This detracts from the UK's strong record on regulatory independence and the fact that the UK still has a relatively strong regulatory framework within the OECD membership. Concerns about policy uncertainty are reflected in the conclusions on infrastructure planning reached by the UK's National Audit Office (NAO) in 2013. The NAO pointed to policy uncertainty as one of the major risks adversely affecting private infrastructure investment (NAO, 2013). Participants concurred that failure to secure political consensus on major infrastructure projects has afflicted successive governments in the UK. The Government's response in 2015 was to set up the National Infrastructure Commission (NIC), headed by a former Minister of Transport from the then opposition party (Box 1).

Box 1. **National Infrastructure Commission: Establishment and remit**

The National Infrastructure Commission (NIC) was set up in October 2015 to look at the UK's future needs for nationally significant economic infrastructure, help to maintain UK's competitiveness amongst the G20 nations, and provide greater certainty for investors by taking a long term approach to the major investment decisions facing the country.

Every Parliament the NIC will publish a National Infrastructure Assessment (NIA) setting out the country's infrastructure needs and priorities over a 10-30 year horizon. It will also be tasked with carrying out specific studies into pressing and significant infrastructure challenges.

The Commission published a consultation on the process and the methodology for the National Infrastructure Assessment on 26 May 2016. The consultation closed on 5 August 2016 and it was followed by a call for evidence which was published on 27 October 2016.

For more details, see https://www.gov.uk/government/consultations/national-infrastructure-assessment-consultation and https://www.gov.uk/government/publications/national-infrastructure-assessment-call-for-evidence.

Discussions among the participants as to how a stable framework could best be achieved confirmed that the establishment of an independent statutory body (like the NIC) to lead the planning process is the most promising way of anchoring spending to a long-term funding commitment independent of the election cycle. Such an institutional setting should have the benefit of enhancing transparency and

reducing the impact of short-term political exigency. Most importantly, it should help increase the longevity of infrastructure plans and ultimately reduce the cost of projects.

The participants made it clear that replacing politicians with an independent planning body is both difficult and undesirable. The ultimate aim of an independent planning body is not to remove the decision-making capacity from politicians, as that would also remove the necessary leadership and commitment, but to provide politicians and other stakeholders with the full range of information on which to build decisions.

Clearly no framework can or indeed should shield infrastructure investment plans entirely from changes in government policy. All infrastructure investment decisions are ultimately political and no socio-economic assessment tools will ever replace political decision-making. But assessment tools and planning institutions can be used to help improve the quality of political decisions and increase the role of deliberation in decision-making. They can also provide the space needed for sufficient attention to be given to any negative impacts of strategic national projects in order to achieve compromise with local political interests.

Government infrastructure investment planning: Objectives

The impact on productivity and economic growth is often a key component of the case for infrastructure investment, particularly in the transport sector. While it is widely recognised that infrastructure is crucial for economic growth, how much and what kind of infrastructure investment should be provided is subject to debate. The participants agreed that there is a challenge of developing a framework that would help decide how to split funding into new investment and infrastructure renewal/maintenance. The participants also stressed the need for combining infrastructure planning with other policies to foster economic growth, such as combining infrastructure planning with incentivising the development of business activity.

Defining the need for infrastructure investment

Provision of adequate infrastructure is a very important component of a country's success. That infrastructure matters to economic growth is relatively well-recognised by policy makers. This recognition is reflected in surveys of economic competitiveness. The quality of infrastructure networks is an important consideration when determining how competitive a country is relative to its peers (IMD, 2016; WEF, 2016). For example, in the World Economic Forum's ranking of global competitiveness the quality of infrastructure is an important component of the overall competitiveness score, accounting for between 5-15% of the overall competitiveness score depending on the country's stage of development.

Insufficient or misallocated investment in infrastructure undermines productivity and economic growth. The experts convened by the ITF noted that this is a real rather than imaginary problem both in the UK and globally. They noted, however, that the scale of the problem may be somewhat exaggerated by how some publications on infrastructure investment interpret evidence.

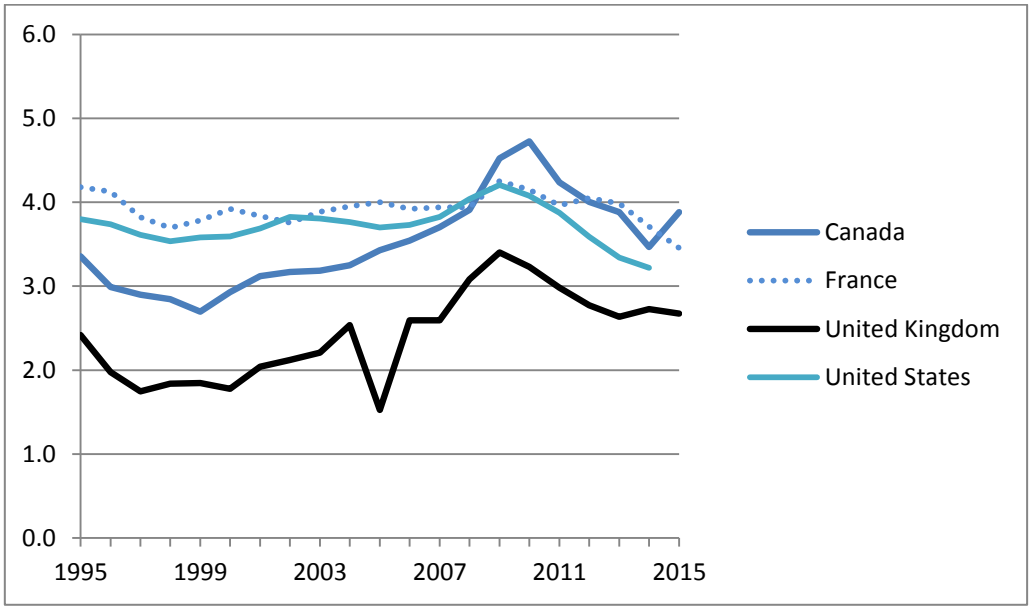
Global infrastructure investment trends are more than reflected in the UK's infrastructure investment levels. Over the past two decades, the UK has invested less public money in infrastructure than other advanced countries like Canada, France or the US (Figure 1).

Private investment in transport infrastructure amounts to only a few percentage points of the total investment in the sector. This is different from the energy and water sectors, where the UK has relied on private investors for infrastructure investment more than other countries and most infrastructure in these sectors is now private.

But how much and what kind of infrastructure matters to long-term economic growth is still subject to debate (see, for example, an excellent literature overview by Straub, 2011). During the event some particular studies were discussed to shed more light on the investment need in the UK and other developed economies. In particular, the IMF found statistically significant and long-lasting effects of public investment on economic growth. In advanced economies, an unanticipated 1 percentage point of GDP increase in infrastructure investment spending increases the level of output by around 0.4% in the same year, and 1.5% after four years.[3] The study demonstrates that developing countries tend to have lower efficiency of public investment: the impact on output was smaller, at around 0.25 in the same year, and 0.5 after four years (IMF, 2014). The report, in line with similar such studies, focuses on public investment in capital and infrastructure in a broad sense and does not distinguish between new infrastructure investments, upgrades to and maintenance to the existing infrastructure stock.[4] It does

however point to signs of aging infrastructure and insufficient maintenance and investment affecting the quality of the existing infrastructure stock in some advanced economies.

Figure 1. **The United Kingdom has spent less on infrastructure compared to peers**



Note: Gross fixed capital formation (per cent of GDP).
Source: National Accounts at a Glance - June 2016, OECD.Stat.

Despite evidence of high rates of return, operations and maintenance spending is often neglected in favour of building new infrastructure (Rioja, 2013), and is sometimes one of the first budget items to be pared back in times of fiscal pressure (Adam and Bevan, 2014). But reducing maintenance expenditure is not equivalent to true fiscal savings from a longer-term perspective: potholes that are not filled today will have to be filled eventually, possibly at a higher cost (IMF, 2014). Investment in maintaining high quality infrastructure and removing capacity bottlenecks is also likely to be more beneficial to the economy than investment in new infrastructure unless patterns of demand are expected to change significantly. This is because relieving congestion produces immediate benefits and such projects are much less subject to uncertainty than new infrastructure. Moreover, investment in maintenance prevents physical deterioration of infrastructure which at a certain point becomes irreversible. At the same time pricing strategies to internalise congestion costs may yield greater welfare gains than removing bottlenecks.

Building infrastructure alone does not create economic potential. An infrastructure project for which there is little latent demand is unlikely to improve productivity and drive economic growth. Participants stressed the importance of planning large strategic infrastructure investment projects as a package – not only across different sectors of economic infrastructure, but also across different policies, to create clusters of economic development.

In the UK transport sector the Jubilee Line is often quoted as an example of a “packaged” solution – coupling the development of the line with favourable business property tax rates that attracted business investment to the Docklands area of East London. Similarly, the success of the Oresund fixed link between Copenhagen and Malmö was dependent on major investments in universities and science parks, mixed with housing, on both sides of the straights as part of a joint policy between the governments of

Denmark and Sweden to create a pole of high tech activity in the region. The short ramp up time and then overtaking of the forecast for use of the rail and road services on the bridge and tunnel linking the two countries reflects the demand created by this broader economic development policy as well as the productivity effects of integrating the labour and service markets of the two cities (Danish Ministry of Transport, 2015; OECD, 2013; UCL, 2015).

Planning objectives in the United Kingdom

In the UK, impact on productivity and economic growth is a key component of the case for some transport infrastructure projects. Individual public sector projects are assessed comprehensively using a five-case assessment model following guidance set out by the Treasury in the Green Book (HMT, 2013) to establish the economic case from a social welfare perspective and the commercial business case and review deliverability, while focussing on the value-for-money aspects of the assessed scheme. The methodology has been developed progressively and is now applied systematically to a wide range of infrastructure projects. Privatisation of energy, water and some transport infrastructure in the 1980s and 1990s, designed to make infrastructure provision market led, reduced the importance of long-term sectoral development plans. In parallel, environmental assessment procedures introduced a new element of strategic planning, notably for major projects with Strategic Environmental Assessment requirements for projects to be examined in relation to development of strategic corridors (ECMT, 2004).

Over the past decade, a deficit in strategic infrastructure planning became apparent and suggestions were made on how to address it. The LSE Growth Commission (LSE, 2013) which was set up to "provide authoritative and evidence-based policy recommendations that target sustainable and inclusive long-term growth in the UK" urged the UK Government to address the failure of infrastructure policy in the UK through building a new institutional architecture to govern infrastructure strategy, delivery and finance by establishing three new institutions:

- an Infrastructure Strategy Board (ISB) to provide strategic vision and foster building cross-party consensus in order to facilitate long-term policy making
- an Infrastructure Planning Commission to deliver ISB's strategic priorities
- an Infrastructure Bank to facilitate infrastructure financing.

In 2013, the Labour Party commissioned an independent expert review of long-term infrastructure planning, headed by Sir John Armitt. The Armitt Review (Armitt, 2013) considered:

- what institutional structure will best support the type of long-term strategic decision-making that is demanded by infrastructure planning and implementation
- how the cross-party consensus that is fundamental to actually delivering upon these decisions can be forged.

The Review urged the Government to establish a new National Infrastructure Commission with statutory independence. In 2015, the National Infrastructure Commission was established under the leadership of Lord Adonis, who left his position as the opposition whip, with a remit to enable better long-term strategic decision-making to build effective and efficient infrastructure for the UK.

The National Infrastructure Commission was set up to identify the UK's strategic infrastructure needs over the next 10-30 years and to propose solutions to the most pressing infrastructure issues, in order to support sustainable economic growth across all regions of the UK, and improve competitiveness and quality of life.

The NIC's National Infrastructure Assessment will be the first-ever multi-sector strategic infrastructure planning exercise in the UK. The NIC is using both bottom-up and top-down approaches to identifying the need for investment across sectors of the economic infrastructure, defined as transport, energy, water and sewerage, flood risk management, digital and communications, and waste (NIC, 2016).

Further institutional reform was implemented in 2016 when Infrastructure UK and the Major Projects Authority were brought together to form the Infrastructure and Projects Authority (IPA). The IPA reports jointly to the Treasury and Cabinet Office, pooling expertise in the financing, delivery, and assurance of major projects in a single unit to support project development and delivery across government. IPA is in charge of producing a National Infrastructure Delivery Plan (NIDP) every five years. The NIDP sets out the path towards achieving the plans set out by the NIC's National Infrastructure Assessment. As such it tackles the Government's highest priority infrastructure plans across all sectors of economic infrastructure. In 2016, housing and social infrastructure were added to the NIDP (IPA, 2016). The NIDP also includes details of the government's on-going work to improve the prioritisation, performance, and delivery of infrastructure, including building a skilled workforce, reducing costs, and encouraging private sector investment.

Planning objectives in other OECD countries

The high-level objectives set out for infrastructure investment in the UK are very similar to the infrastructure planning objectives set in planning frameworks in other OECD member countries.

The experts discussed objectives set in a few selected planning frameworks:

- New Zealand's vision in its National Infrastructure Plan is to make country's infrastructure resilient and co-ordinated so that it can contribute "to a strong economy and high living standards" (NIU, 2015).
- Australia's Infrastructure Plan is based on delivering four outcomes: productive cities, productive regions, efficient infrastructure markets, sustainable and equitable infrastructure, and better decisions and better delivery (IA, 2016).
- In Japan, the first consolidated long-term infrastructure plan developed in 2003 was adopted in a context of fiscal constraint with stagnant economic growth. As the Ministry of Finance explained in a note on the Budget for 2003[5] infrastructure investment was to be driven by the objective of economically catching up to other western economies that were estimated to have a larger stock of assets relative to the size of their economies. The harsh fiscal environment however forced a refocusing on more effective use of public funds. The current plan[6] adopted in 2015, has four major objectives: strategic maintenance and renewal; reduction of risks from natural disasters; regional sustainability under conditions of a declining and aging population; inducing private investment and facilitating economic growth.
- In France, the 2013 Mobilité 21 Agenda (Mobilité 21) that guides transport infrastructure investment is, like in Australia, driven by multiple priorities: optimise existing transport systems to limit greenfield infrastructure projects, improve system performance and territorial connectivity, improve environmental performance of transport systems, and minimise the environmental impact of transportation systems and infrastructure (Mobilité 21, 2013).
- In the European Union, investment in energy infrastructure is driven by the overarching objective of achieving the EU's long-term greenhouse-gas reductions targets by 2050. The

strategy is also driven by high-level objectives of creating a more competitive, secure, and sustainable energy system. Investment in the energy sector in each member country is driven by EU-wide targets and policy objectives. The targets and objectives for 2020-2030 were agreed on by all EU member countries and outlined in a new 2030 Framework for climate and energy (EC, 2016).

- Long-term greenhouse gas emissions reduction targets as an overall constraint are also reflected in the strategic investment assessment in the UK. For example, in the assessment of airport capacity expansion undertaken by the Airports Commission between 2013 and 2015 scenarios were developed to test the resilience of expansion options under specific carbon constraints, as specified by the UK Committee on Climate Change (CCC, 2013).

A discussion of the selected examples revealed that setting objectives for long-term infrastructure planning is challenging for a number of reasons. First of all, because infrastructure planning needs to rely on a set of forecasts with respect to uncertain future, it is virtually impossible (and potentially unhelpful) to come up with a detailed list of objectives that strategic infrastructure projects should deliver. That perhaps explains why objectives set across the planning frameworks investigated in the roundtable as well as the objectives guiding the NIC are set at a very high, strategic level. Some participants argued that ensuring that objectives are high-level and strategic when determining the future infrastructure need should help future-proof investment plans.

On the other hand, high-level objectives mean that projects are open to interpretation and re-interpretation by politicians, experts and the public. Some participants argued that high-level objectives are rather unhelpful since they often change with the government. The table below sets out an example of how the planning objectives recently evolved in France when Mobilité 21 replaced the SNIT (Schema national des infrastructures de transport), the previous strategic planning exercise.

Table 1. **Infrastructure planning objectives' changes in France**

SNIT	Mobilité 21
1. Guarantee the quality of transport infrastructure	1. Optimise existing transport systems to limit greenfield infrastructure projects
2. Upgrade the quality of transport services	2. Improve systems' performance and territorial connectivity
3. Improve the performance of railway systems	3. Improve environmental performance of transport systems
4. Experiment with innovative governance and financing mechanisms.	4. Minimise the environmental impact of transportation systems and infrastructure

Source: Mobilité 21 (2013) and SNIT (2011).

Such changes most often stem from changes in the planning paradigm. This can be driven by a change of government (and the policy direction associated with it), often in response to external factors and a changing global policy environment. For example, France's Mobilité 21 Agenda was a response to the impact of the global financial crisis on public finances as well as a strong political focus on reaching the country's environmental objectives and promoting sustainable mobility.

The previous National Transport Infrastructure Plan (known as SNIT and adopted in 2009) did not include such explicit environmental objectives. Rather, SNIT's objectives focussed on quality and innovation in transport planning, as well as developing more effective techniques of project appraisal (see Table 1). More than anything, however, France's change of objectives was a response to the economic consequences of the 2007/8 financial crisis. The introduction to Mobilité 21 is explained in Table 1.

The SNIT, developed by the previous government, comprises many new rail, road and waterway links together with investments in the existing networks. The overall volume of these investments is estimated at EUR 245 billion over 25 years. The State would be required to contribute EUR 90 billion whilst annual expenditure on infrastructure by the State stands at EUR 2 billion. The SNIT also foresees that local governments will contribute EUR 56 billion, which is also out of proportion. The SNIT is incompatible with a return to balanced public finance.

Government infrastructure investment planning: Process and methodology

Review of infrastructure planning strategies in the transport and energy sectors revealed some high-level similarities:

- The assessment of need for infrastructure investment is predominantly driven by population and economic growth rates.
- Scenarios are used to consider different possible outcomes.
- Different forms of stakeholder consultation are part of the process.

At the same time, the experts noted that it is relatively uncommon for infrastructure plans to be developed using both bottom-up and top-down approaches. Most planning is driven by a bottom-up process to assess the need for specific sectors or locations. This also means that detailed assessments of the location of population and economic growth are relatively uncommon.

United Kingdom

Within the transport sector there are separate five-year plans and funding settlements for the national rail and strategic road networks.

For strategic roads, the government published the first Road Investment Strategy (RIS 1), in December 2014 and updated it in March 2015 (RIS, 2015). This outlines a multi-year investment plan including over 100 major enhancement schemes (widening roads, investing in managed motorways, etc.), plus maintenance and renewals work, funded by GBP 15.2 billion of public money. The RIS 1 comprises:

- a multi-year investment plan that will be used to improve the network and create better roads for users
- high-level objectives for the first investment period, 2015 to 2020, to enable the more efficient, effective, and innovative delivery of a safer and more reliable network and underpinned by more funding certainty.

The RIS 1 requires Highways England, a government-owned strategic highways company managing the strategic road network, to equally focus on eight areas, including safety and efficiency, which back the strategic vision for the road network. It also outlines a set of performance indicators against which the company will be assessed. Work is now underway to develop the second RIS covering the 2020-2025 period, starting with a research phase comprising six strategic studies and a programme of refreshed route strategies covering the entire network. The strategic study reports were completed at the end of 2016. Highways England will also revisit and refresh its 18 route strategies that identify the pressures on and needs of the network.

For the rail network infrastructure, programmes of work are managed in Control Periods set by the sectoral regulator or the Office for Rail and Road Regulation (ORR), typically of five years duration. The current Control Period 5 (CP5) runs from April 2014 to March 2019 and the CP5 delivery plan, together with an Enhancements Delivery Plan, sets out the funding and outputs for Network Rail (the organisation

responsible for managing the rail network infrastructure). To respond to the rapid increase in demand for rail travel in the UK (passenger journeys have more than doubled since 1995) CP5 includes a major programme of electrifications and other enhancements. Delivery of these will extend into the next Control Period (and in late 2016 several projects were postponed). The CP5 settlement also sets agreed levels of maintenance and renewal work. Work is underway to prepare for the next rail Control Period settlement, which will take effect from 2019.

An independent body, the ORR, has an important role in regulating the infrastructure and monitoring delivery of both the rail and strategic roads five-year plans. It reviews the government demands for enhancements, the High Level Output Specification, for reconciliation with a Statement of Funds Available in the light of the efficiency targets it establishes for Network Rail.

Train operations are delivered by separate private companies which bid for franchises determined by the Department for Transport.

Separate to all of the above, the UK plans to build a north-south high-speed rail link, HS2, which is at an advanced stage of development. Construction work is due to start in 2017, subject to Royal Assent.[7] Given its advanced stage of planning HS2 is not subject to the purview of the NIC. In many ways, the cross-party support (albeit subject to objection within each party) for HS2 was the precursor for the establishment of the Commission. Agreement has emerged over the last decade across the political spectrum that changes of government should no longer routinely result in suspension of plans for long-term infrastructure investment in order to have them reviewed, with the inevitable, prolonged delays that result.

At the same time, some of the shortcomings in decision-making demonstrated by the planning process behind HS2 led the government to set up the NIC with the aim of creating an institutional framework for continuity. Planning for HS2 has been characterised by some observers as lacking a process of structured deliberation (King and Crewe, 2016).

For energy infrastructure, the Government's approach to energy policy is to balance the trade-offs between ensuring sufficient supplies of gas and electricity, whilst ensuring the lowest possible cost to consumers, and at the same time meeting legally binding environmental targets.

Infrastructure Australia

Australia has a tradition of project-based planning, without sectoral master plans. Like the UK, Australia is now developing a more comprehensive and long-term strategic approach to infrastructure development.

The experts convened by the ITF noted that the creation of Infrastructure Australia (IA) had several positive impacts on infrastructure planning. The creation of an independent body was welcomed by the stakeholders and managed to secure more bi-partisan support for project priorities. It also added greater transparency and visibility to the process of project selection and prioritisation.

Infrastructure Australia encouraged a greater focus on cost-benefit analysis as a basis for decision making. An Infrastructure Priority List was also created to guide decision makers. The discussion at the expert roundtable revealed that focus on policy and reform, in addition to project appraisal and prioritisation, added depth and credibility to the organisation. This has allowed it to avoid the perception of delivering a simplistic pipeline of projects.

Background to creating Infrastructure Australia

Despite the fact that Australia has been a federation since 1901, when six separate colonies agreed to unite and form the Commonwealth, it bears many similarities to the UK in terms of its culture and institutional heritage. Its infrastructure planning also, despite the fact that it is a federation, is largely harmonised across levels of government.

Australia is a federal country where semi-sovereign jurisdictions retain the primary responsibility for infrastructure provision. However, with constrained fiscal capacity at the semi-sovereign level, the Commonwealth (federal) Government makes a modest, but catalytic investment contribution towards projects of national significance.

Responding in part to a perception that there was insufficient involvement in infrastructure planning at the national level, since 2008 the Commonwealth Government has taken a more top-down planning approach with the establishment of IA. Now in its second iteration (having had its independence and mandate strengthened in 2014), IA has a mandate to prioritise and progress nationally significant infrastructure projects and reforms. Infrastructure Australia's mandate specifically includes the development of periodic Infrastructure Audits, the Australian Infrastructure Plan and a regularly updated Infrastructure Priority List.

Infrastructure Australia was created to address an inconsistent approach to planning infrastructure investment which focussed at the level of individual projects, without an adequate assessment of need or defining the problem at hand from a national perspective. Amongst other challenges, infrastructure investments were sometimes announced in the absence of an appropriate business case and underpinning economic assessment.

The Australian Constitution grants the Commonwealth Government control over areas of national interest such as defence and the regulation of corporations, while the states retained control over major areas of service delivery such as health, education, and most of their infrastructure. However, due to the Australian war effort in the 1940s, the Commonwealth took over the states' main source of revenue – income tax. This move left the states with substantial service delivery responsibilities and limited funding, while the Commonwealth retains the major revenue raising capacity – this is known as a Vertical Fiscal Imbalance and has significant implications for infrastructure funding.

The states retain responsibility for two of the largest expenditure items – health and education - without the ability to pay for these items from their own revenue base. To offset this imbalance, the Commonwealth Government pays the states' grants to cover their responsibilities. For every dollar a state government spends on police, transport, education or health, around 50 cents comes directly from the federal government. The structure allows, in some circumstances, for the Commonwealth Government to influence or mandate how money is spent at the state and territory level, but can also result in "passing the buck" between levels of government of who is responsible for the lion's share of funding in particular areas or assets.

The Australia Infrastructure Plan

In February 2016, IA released the first-ever 15-year Australian Infrastructure Plan and Infrastructure Priority List (IA, 2016). The Australian Infrastructure Plan is a reform document detailing major changes required across energy, telecommunications, water, and transport to meet the forward infrastructure and growth challenges; while the Infrastructure Priority List develops a forward perspective on the specific investments that will be required to meet demand. Both documents are informed by Infrastructure Australia's 2015 Australian Infrastructure Audit.

The Australian Infrastructure Audit created an evidence base to analyse the challenges pertaining to Australian infrastructure. Extensive amounts of data were collected on major capital cities, corridors, population, and a lot of modelling of congestion was done. IA went on a national road show to raise the issues regarding the Audit, and seek submissions on solving the problems identified. It also consulted widely on policy and reform component of the Australian Infrastructure Plan and received submissions from a diverse group of stakeholders, while working closely with the independent Board. The collected evidence base as well as the inputs from stakeholders provided a "bottom-up" planning perspective.

The Australian Infrastructure Plan and the Infrastructure Priority List are further underpinned by a detailed "place-based" analysis to provide a "top-down" planning perspective. The analysis projected current and future demographic and economic characteristics for 73 regions of the country. IA also estimates the direct economic contribution (DEC) and gross value added measures for each of the regions. The regions with greatest increases in DEC over time are identified as "hot spots", and efforts are put into assessing what kind of investment will help drive the greatest economic impact in these regions. The "hot spots" are located in Sydney, Melbourne, Brisbane and Perth where three-fourths of Australia's population growth is expected to occur between 2011 and 2031.

IA's Infrastructure Priority List aims to provide structured guidance to decision makers and was created using both top-down and bottom-up approaches. To encourage a long-term perspective, the projects were divided up into two groups:

- Initiatives: priorities that have been identified to address a nationally significant need, but require further development and rigorous assessment to determine and evaluate the most appropriate option for delivery.
- Projects: priorities that have undergone a full business case assessment by Infrastructure Australia and that will address a nationally significant problem and deliver robust economic, social or environmental outcomes.

The list retains flexibility and is periodically updated in order to respond to emerging challenges and opportunities. In fact, the list has already been updated a number of times since it was first published, reflecting emerging challenges and the development of business cases meaning "Initiatives" have graduated to become "Projects". The list also defines a priority or high priority status for initiatives and projects, reflecting the scale of the problem being addressed.

The IA list does not provide an ordered ranking, but serves as a tool for decision makers to assess projects on a number of different criteria. Potential investments are assessed both in terms of their benefit-cost ratio (BCR) and in their strategic value – evaluating the problem they solve, the extent to which they solve it, and how they fit within existing networks. This feature makes the list potentially useful to the decision makers even if the planning objectives are modified due to changing government priorities.

Scenario planning

Infrastructure Australia does not explicitly use scenarios for its planning work, but its Australian Infrastructure Audit made an attempt to deal with some of the uncertainty around infrastructure planning over a long period of time (IA, 2015). In preparing the audit, IA engaged a private consulting firm to prepare economic analysis of significant national infrastructure. The analysis used three scenarios to inform the audit and predictions of where infrastructure gaps were likely to arise (IA, 2015: 15). The three scenarios were:

- a base case using a standard population growth assumption
- a high population growth scenario
- a scenario that tested the potential implications of decisions aimed at improving the productivity of the infrastructure sectors.

In addition to different population and productivity scenarios, the audit also acknowledged other uncertainties. However, it did not undertake economic analysis using scenarios relating to those uncertainties. The other recognised uncertainties were (IA, 2015: 40):

- the implications of demographic change such as an aging population
- shifts in decades-long demand patterns such as greater demand for inner city housing
- the scope of technological change such as intelligent transport systems or the spread of energy storage technology
- changes in the global and local economy
- the future of work
- the response to climate change.

Developing national governance architecture

The establishment of Infrastructure Australia at the national level has also initiated a proliferation of similar infrastructure bodies at the state level. Though varied in form and function depending on the nuances of the particular jurisdiction, most of the bodies retain some degree of independence from government and have a mandate to define and prioritise infrastructure investment options.

Australia's largest states, New South Wales, Victoria and Queensland have established the following independent infrastructure bodies:

- Infrastructure New South Wales was established under the Infrastructure NSW Act 2011 (INSW).
- Infrastructure Victoria was created by the Infrastructure Victoria Act 2015 (IV).
- Building Queensland was established by the Building Queensland Act 2015 (BQ).

Both INSW and IV develop long-term infrastructure plans: a 20-year infrastructure plan in the case of INSW and a 30-year plan in the case of IV. BQ's mandate has a closer focus on the business case development, while the function of long-term strategic planning has been retained within the Queensland Government through the development of a State Infrastructure Plan.

These plans, whether produced by independent statutory bodies or within state governments, typically form the basis of submissions to Infrastructure Australia's long-term planning and the continual update of the Infrastructure Priority List.

Electricity planning in France and Europe

France serves as a good example of how a strong tradition of national long-term planning for electricity generation, distribution, and transmission has evolved to integrate the market led policies adopted at the European Union level. It nationalised its electricity and gas production, transmission, and distribution industries as vertically integrated monopolies (EdF and GdF) in 1946. In the same year

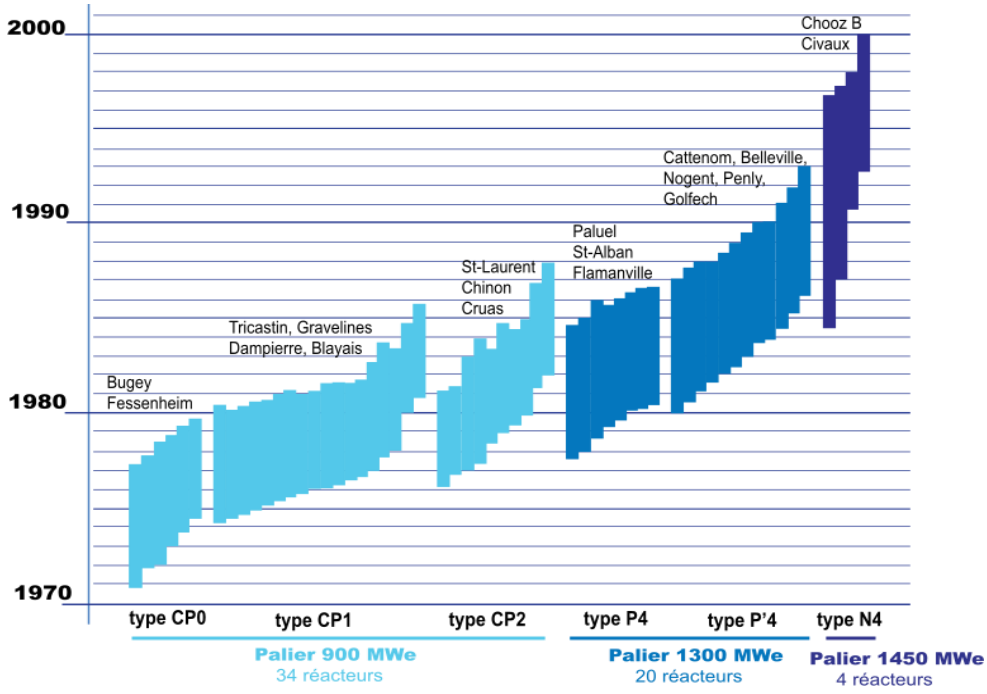
France adopted a national planning system that guided economic development until 1992. Reconstruction and renovation of thermal electric and hydroelectric plants was a fundamental part of the national plan.

The Energy Transition Law and other EU sustainability targets introduced in France have potentially created additional uncertainties for investment in the electricity sector. In particular, the issues relating to security of energy supply might be exacerbated by the cap on nuclear generation. Moreover, the dependence of renewable generation on regulatory arrangements for buying power at a guaranteed price makes regulatory risk the key factor in determining investment decisions. The same can be applied to nuclear power in the UK.

Electricity generation

One of the most important objectives of the national plan in France was to reduce uncertainty for investment decisions. However, reaching that objective proved more difficult with the oil shocks of 1973 and 1979. The oil shocks triggered two major new directions in French electricity generation planning: a focus on the international competitiveness of French industry and accelerated development of nuclear power. Another big shift in planning was seen in the 1980s when decentralisation of government was coupled with the introduction under the national plan of contracts between the State and the Regions, governing amongst other things responsibilities for funding infrastructure investment.

Figure 2. **Programming of the construction of nuclear reactors in France**



Source: IRSN (n.d.).

Financing of investment by state-owned industries under France's national plan was overseen by an Investment Commission within the Ministry of Finance. Construction of EdF's nuclear power plants was planned to pay down the debt raised for investment with sales of electricity, priced at long-run marginal cost. This has played out successfully for EdF although the costs of decommissioning reactors are proving somewhat higher than expected.

French energy policy currently focusses on developing renewable energy to reduce CO_2 emissions whilst diversifying away from nuclear power. The Energy Transition Law (2015), see Box 2, caps nuclear power at 63.2 GW installed capacity, which means two reactors will need to be retired when the Flammenville EPR comes on stream.

Box 2. **France's 2015 Energy Transition Law**

The Energy Transition Law was passed after two years of debate with the following main objectives:

- Reduction in CO_2 emissions of 40% between 1990 and 2030 in line with EU engagements and in preparation for COP21
- Reduction in total final energy consumption of 50% between 2012 and 2050
- Reduction in fossil fuel consumption of 30% between 2012 and 2030
- Target of 32% renewable energy in total final energy consumption in 2030 compared to 14% in 2012
- Target of 50% nuclear energy in electricity production in 2025 compared to 77% in 2014.

The nuclear target was opposed by opposition senators, but adopted by the majority in the lower house. The law provides for a master plan, known as the *pluriannual* energy program, to be revised periodically to establish priorities for government intervention and investment across the energy sector.

Source: Connaissance des Énergies, http://www.connaissancedesenergies.org/loi-de-transition-energetique-les-deputes-adoptent-le-texte-definitif-150723

The Energy Transition Law, EU sustainability targets, and similar policies in other European countries, have all created additional uncertainties for investment in the electricity sector. The law and an apparent lack of cross-party consensus create regulatory uncertainty over the market conditions for building new base load capacity, which has been primarily nuclear. Security of supply issues are exacerbated by the cap on nuclear generation. New peak supply options will also be needed and additional incentives for demand responsiveness (large consumers shutting down in periods of peak demand) created; the contracts for difference that underpin investment in renewables may need to be extended to non-renewable generation to guarantee supply in the peak period, given the intermittence of many renewable sources. Investment in smart metering (Linky project) to enable the development of smart grids will be required, but the demand for this type of system is uncertain. Above all, the dependence of renewable generation on regulatory arrangements for buying power at a guaranteed price makes regulatory risk the key factor in determining investment decisions. The same can be applied to nuclear power in the UK.

Electricity transmission and distribution

The strategic planning framework for the electricity generation, transmission and distribution systems in France is summarised in Figure 3. Each year, the transmission system operator (RTE) publishes a ten-year national development plan that describes current and future investment needs on the transmission network. This is assessed by the Commission de Régulation de l'Energie (CRE), which consults users and verifies that the plan meets investment needs and is consistent with the non-binding investment plan established by European transmission system operators. The CRE can impose amendments. The plan mainly focusses on the investment needs of the high voltage network (225 kV and

400 kV). A similar planning exercise is conducted every two years at the European level by the European Network of Transmission System Operators for electricity (ENTSO-E).

Figure 3. **French strategic planning framework for electricity**

<table>
<tr><th colspan="2">Sector</th><th>Economy</th><th colspan="2">Role of public authority in planning / the approval of the investment decision</th><th>Incentive mechanisms</th></tr>
<tr><td colspan="2">Gas/electricity transport grids</td><td>Monopoly</td><td colspan="2" rowspan="2">Approval of regional plans for the integration of renewables (S3RENR): préfet, local representative of the State)
Approval of ten year national development plan of transmission system operator (TSO): regulator</td><td rowspan="2">Incentive regulation (interconnections, quality of service)</td></tr>
<tr><td colspan="2" rowspan="2">Gas/electricity interconnections and LNG terminals</td><td>Monopoly</td></tr>
<tr><td>except for exempted infrastructure (Dunkerque LNG, Eleclink)</td><td colspan="2">Exemption decision: regulator(s)</td><td></td></tr>
<tr><td colspan="2">Gas/electricity distribution grids</td><td>Monopoly</td><td colspan="2">Indicative : local conferences (100) between 600+ conceding authorities and distribution system operators (DSOs), chaired by the préfet</td><td>Incentive regulation (smart meters, quality of service)</td></tr>
<tr><td colspan="2">Electricity in insular areas (Corsica, Martinique, Guadeloupe, La Réunion)</td><td>Integrated monopoly (grids and supply)</td><td>Local pluriannual energy program (PPE)</td><td>Approval of coverage of expenses by regulator</td><td></td></tr>
<tr><td rowspan="3">Electricity generation</td><td>Nuclear</td><td>de facto monopoly</td><td rowspan="3">PPE at national level (basis for the ministry of energy to grant / withdraw operating licenses)</td><td rowspan="2">Govt as EDF's shareholder.
Nuclear safety authority (ASN) authorises operation every 10 Y & sets safety standard</td><td></td></tr>
<tr><td>Renewable sources</td><td>Subsidised market</td><td>Feed-in premium</td></tr>
<tr><td>Other</td><td>Market</td><td></td><td>Capacity markets</td></tr>
</table>

Source: Ollier (2016).

To assess long-term infrastructure needs, RTE simulates constraints on the transmission system to a 2030 horizon using four scenarios (Table 2). The uncertainties affecting network planning are reflected in financial trajectories associated with each scenario. A short summary of two of the scenarios illustrates the large degree of uncertainty in the outlook for demand and supply (see Figure 4). The low growth scenario is characterised by a drop in consumption (50 TWh compared to current demand), stability in the share of nuclear generation and a small increase of renewable energy by 2030. The new mix scenario is characterised by stability of demand, a large reduction in the share of nuclear energy (25.5 GW in 2030 compared to the current level) and a large increase in renewable energy supply by 2030 (48 GW in 2030 compared to the current level)

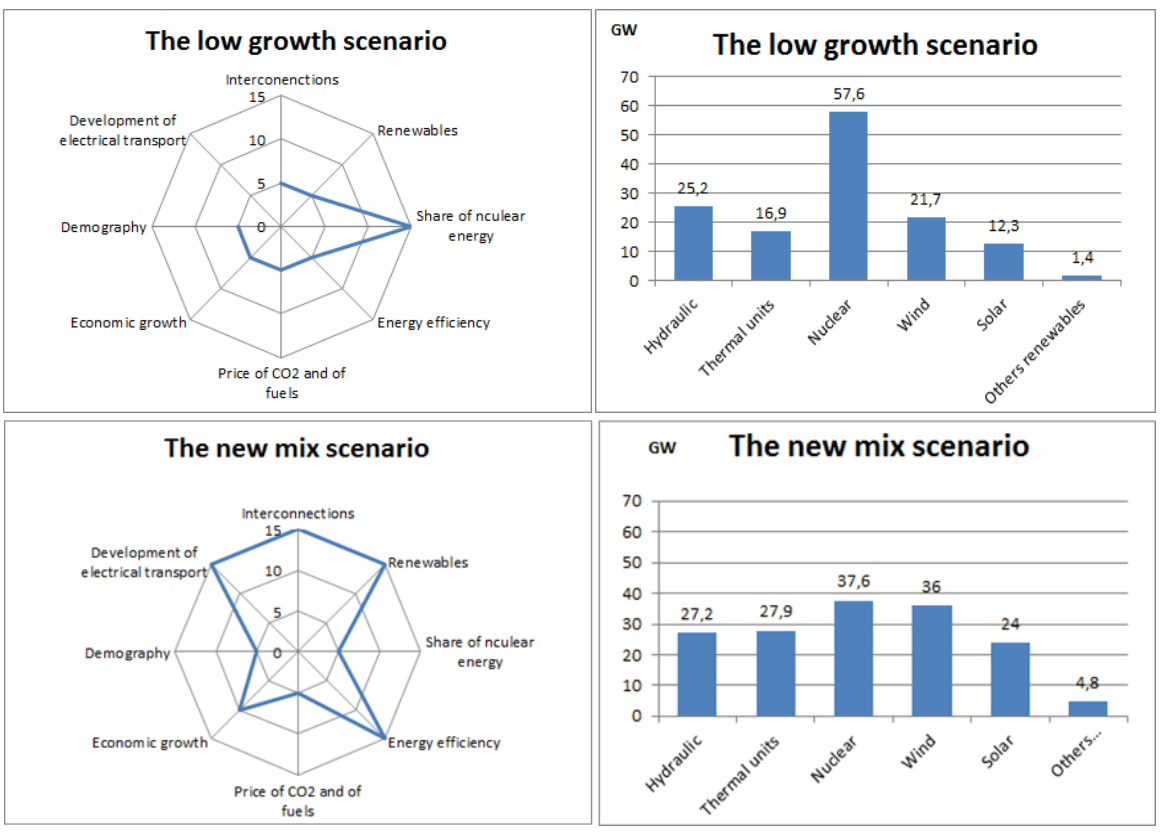
At the European level, ENSTO-E analyses interconnection development needs, while also considering the four scenarios. These are based on national assumptions but when aggregated at the European level they can lead to overestimation of parameters such as generation or demand. The cost-benefit analyses performed under the European 10-year development planning exercise also reflects the general uncertainties of network planning, as only a few projects are beneficial in all scenarios. The European planning exercise thus cannot provide a definite answer on which projects should be built, but it is a useful platform for increasing the consistency of national energy policies and the comparability of national network development plans.

Table 2. **Scenarios for assessing long-term transmission infrastructure needs in France**

	Scenarios			
Financial trajectories at 10 years (EUR Billions)	**Low growth**	**High consumption**	**Diversified**	**New mix**
Interconnections	0.9	1.9	1.9	2.5
Networks needs on 400 kV networks	1.3	1.8	1.9	2.2
Networks needs on regional networks (63 kV + 90 kV)	2.9	3.2	3.1	3.2
Customer connections	1.9	2.7	2.4	3.7
Renewal of existing assets	4.3	4.2	4.2	4.1
Information systems, real asset	1.9	1.9	1.9	1.9
Total	**13.2**	**15.7**	**15.4**	**17.6**

Source: Ollier (2016).

Figure 4. **Low growth and new mix scenario comparison**

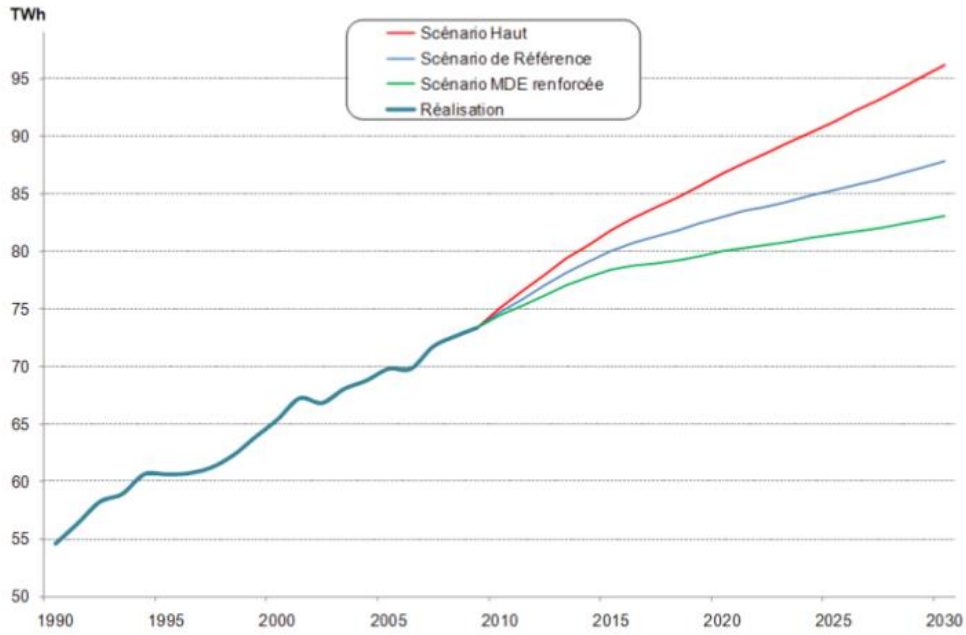


Source: Ollier (2016).

The scenarios are used as follows: for each, a set of projects is retained to solve constraints on the network. Projects common to all scenarios are implemented. For projects specific to individual scenarios, the investment decision is delayed until there is sufficient certainty regarding the assumptions driving demand for it. Investments in the high voltage grid are mainly dependent on the development of cross-border flows, the development of renewables, (which tends to involve north-south transfers of power in Europe) and decommissioning of nuclear power plants. Investments in regional transmission and distribution are being driven by local peak demand and development of renewable power generation.

Multi-sectoral co-ordination: The Grand Paris Express Project

Figure 5. **Electricity demand projections and transmission system for Ile-de-France**



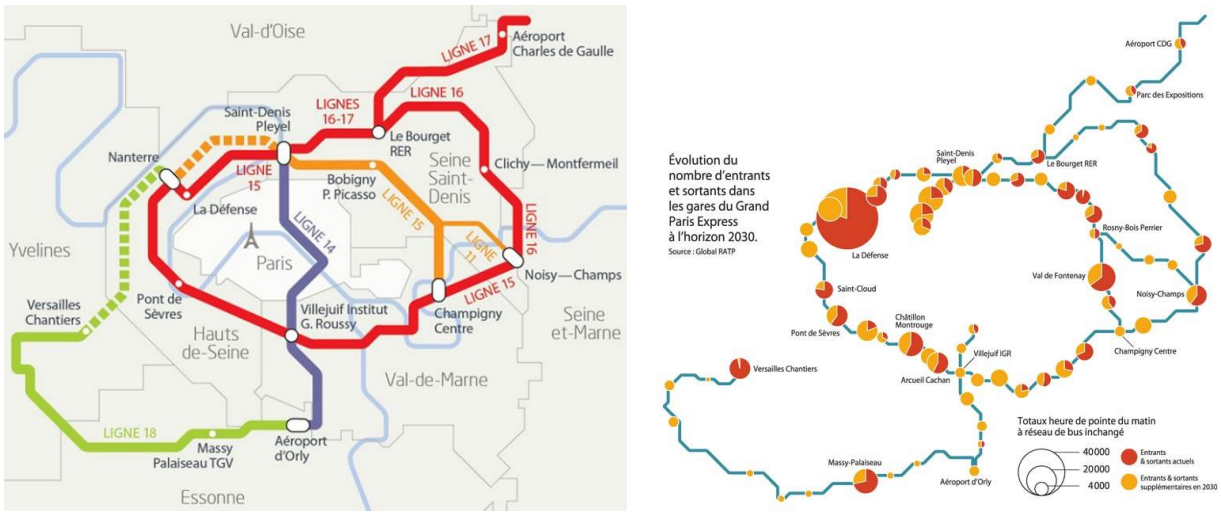
Source: Direction Régional Ile-de-France Énergie et Environnement (2012).

Regional government in France has responsibility for strategic planning based on regional master plans for economic development. For the Ile-de-France Region where Paris is situated, responsibilities in the energy sector cover monitoring the development of electricity demand and producing a master plan for air quality, climate change, and energy. Paris is the largest centre of electricity demand in the country (18%) and is supplied, schematically, through an outer ring of 400 kV transmission lines linking power plants to sub-stations in the outer suburbs and an inner ring of 225 kV transmission lines. Demand is concentrated in the tertiary sector (44%) and housing (33%). Despite the increasing focus of policy on energy efficiency and demand management, demand is expected to continue to grow strongly under all three scenarios developed by the region with RTE (high, reference, and reinforced energy efficiency measures), see Figure 5. Demand for electricity in the transport sector is currently relatively low (5%), mainly from the rail and metro systems, but could grow rapidly with the electrification of road transport.

Development of the EUR 30 billion Grand Paris Express high-speed, automated metro system is intended to structure the development of Paris to ensure that it is a competitive world city. The development will have a large direct impact on transport sector electricity demand and a major impact on shaping the spatial development of housing, offices and industry (Ministère de l'Égalité des Territoires et du Logement, 2013). The project involves 200 km of new electrified rail lines and 68 new stations. An

integrated part of the project is to enable 70 000 houses and apartments to be built a year over 25 years up from the present 42 000 a year. Up to a total of 1.5 million additional homes may eventually be built around the new stations.

Figure 6. **The Grand Paris Express: Route map and increase in passengers using stations in 2030**



Source: Société de Grand Paris (2017); RATP (2017).

To prepare for the impact of the project on electricity supply, the Region examined a scenario at the extreme upper end of the potential, with 1 million new homes built by 2025 in collaboration with EdF, ERdF (distribution) and RTE. Modelling covered new housing and jobs by location, public transport infrastructure, local electricity production, enhanced energy efficiency and technological change, and electric vehicle recharging infrastructure. On this basis, the project will result in an additional 3 300 MW electricity consumption in the region, a 20% increase. This will require a EUR 600 million investment in seven new substations and upgrading of existing transformers in the areas served by the metro system. In addition, the 400 kV transmission line system will need reinforcement to bring power from Normandy (Flammenville) together with investment in the 225 kV network; 15 projects altogether, integrated in RTE's 10-year master plan.

Transport infrastructure planning in France: From sectorial master plans to planning for multimodal mobility and the energy transition

The limits to the master planning approach in France have been exposed by financial crises against a background of maturing networks with declining rates of return on investment at the margin. Fiscal constraints have led France to reprioritise projects on the basis of internal rate of return. This has seen road projects brought to the fore after a decade or more of priority given to rail investment. The road investment was financed through the use of road toll revenues for financing through the AFITF infrastructure agency.

Transport infrastructure master plans fostered agreements between central, regional, and local government on funding investments. In particular, for the Grand Paris Express Project, the extended stakeholder consultation, notably accommodating the mayors of less affluent suburbs east of Paris, generated cross-party support that saw the project survive both the financial crisis and the change of President and governing party. The "user pays" principle is applied to transport infrastructure projects in

France. This may have helped protect the decision maker from the ad-hoc politically motivated projects with low or negative rates of return and it ensures significant revenue.

The other major development in French strategic planning is the replacement of sub-sectoral transport master plans with a multimodal approach. Attention to multimodal interchanges and interconnections and the impact of, for example, rail projects on the road network, has long been part of planning, but the new emphasis is on value-for-money in projects across the modes. This is accompanied by a focus on bottlenecks, notably in deficiencies in port hinterland infrastructure in the north of France, congested rail links, and congested roads.

Master plans

The presence of a strong central administration backed in the regions by the power of prefects on the one hand and local elected officials on the other, has resulted in coherent transport infrastructure planning programmes in France, with 15- or 20-year timeframes. These long-term planning frameworks, called *schéma directeurs* (master plans), have contributed to the success of developing a dense motorway network and the core high-speed rail network.

The role of master plans was re-established by the 1982 law on *Directing development of inland transport*, the LOTI (1982), which continues to guide transport planning today. Under the article dealing with the framework for planning territorial development, the State is required to establish infrastructure master plans in collaboration with regional government to ensure coherent development of transport networks over the long term and establish priorities for modernisation and extension. A new master plan was agreed in 1990 for motorways and followed in 1991 by the first high-speed rail master plan. Both entered into force under a decree issued in April 1992.

Master plans are not programmes for investment because the execution of the projects identified in the plan is decided by the State and SNCF (in the case of rail), the motorway concession holders etc. under framework contracts (*contrats de plan*) agreed on the basis of the macroeconomic situation, traffic trends and financial constraints in the short-term. Commitments to inter-connections with neighbouring countries are also a factor in the framework contracts.

The purpose of the master plan is to assess needs with sufficient lead time for the scale of investment involved. It also facilitates decision making on territorial and urban development that is dependent on the transport network and enables forward planning of dependent and complementary infrastructure, e.g. in the case of high-speed rail, associated development or redundancy of the conventional network. These objectives are clearly set out in the master plans.[8]

Principles for the development of high-speed rail in France were clearly set out in the introduction of the plan as follows:

- Construct new high-capacity lines where traffic can be concentrated along alignments that are as direct as possible, generally reserved for passenger traffic only with the exception of the line and tunnel envisaged through the Alps to Italy.
- Maintain compatibility with the conventional network so that high-speed trains can provide access to destinations beyond the high-speed network.
- Provide high-frequency, high-speed, and direct services with minimal need to change trains.
- Serve the central stations of the largest cities and ensure good access to new out of town stations where these are necessary.

These goals have remained constant over time in contrast to other countries, for example Spain which more recently adopted goals of national integration, while Japan's goal is regional development (ITF, 2015).

Table 3. **High-speed rail lines in the 1991 Master Plan**

Project	Length of line (km)	Forecast internal rate of return for SNCF	Forecast socio-economic rate of return
Aquitaine	480	7.6	10.1
Auvergne	130	3.1	.7
Bretagne	156	7.4	13.6
Est	460	4.3	8.8
Grand sud	70	5.0	12.0
Interconnection sud	49	8.2	9.6
Trans-Alpine link	261	6.0	10.0
Limousin	174	2.4	4.4
Provence	219	9.8	13.0
Cote d'Azur	132	8.4	11.0
Languedoc-Roussillon	290	6.1	9.0
Midi-Pyrenees	184	5.5	6.5
Normandie	169	0.1	3.0
Pays de la Loire	78	5.4	7.7
Picardie	165	4.8	5.0
Rhin-Rhone	425	5.9	10.7

Source: Décret n° 92-355, 1 April 1992.

The master plan for high-speed rail developed in 1991 included a total of 3 442 km (2 326 miles) of high-speed lines (Table 3). The plan was based on estimates of forecast traffic and rates of return on investment. Priorities for investment were based on the internal rate of return for SNCF and the socio-economic return for the community, modifiable by two less quantifiable considerations: the impact on territorial development, including the value of high-speed connections in promoting the competitiveness of large cities within Europe and the potential for high-speed rail to relieve congestion on other transport networks; and the international strategy and the European Union's plans for the development of a high-speed rail network. The master plan is summarised in Figure 7 below, which shows the new lines and travel times from Paris with and without the new infrastructure.

One of the strengths of the French planning system is the requirement to undertake systematic ex-post assessments of public infrastructure investments. This yields the results in Table 4. The high-speed lines were built in order of expected rate of return. Ex-post yields are systematically lower but essentially in the same order. The two projects that break the pattern both saw passenger numbers affected by the later-than-expected construction of the Channel Tunnel rail link, HS1, in the UK.

Table 4. **Ex-ante/ex-post comparisons of socio-economic rates of return for high-speed rail lines**

Year opened	Project	Economic internal rate of return		Principal explanation
		Ex-ante	Ex-post	
1992	Atlantique	23.6%	14.0%	Traffic and revenues higher than forecast, but heavy cost overruns (more than 20%).
1993 Extended to Belgium 1996	Nord-Europe	20.3%	5.0%	Traffic below forecasts largely due to late development of HS1 in the UK; revenues close to forecast thanks to increased fares, but 20% infrastructure cost overrun.
1994	Interconnexion Ile-de-France	14.1%	6.9%	Traffic increases below forecast and overruns on rolling stock and operating costs.
1994	Rhône-Alpes (Valence)	14.0%	10.6%	Benchmark traffic below forecast and overruns on rolling stock and operating costs.
2001	Méditerranée	11.0%	8.1%	Traffic close to forecast but overruns on rolling stock and operating costs.
2007	Est	8.5%	4.2%	Cost overruns (+20.2 %) partially offset by higher-than-expected traffic

Source*:* Bilans LOTI, http://www.developpement-durable.gouv.fr/Bilans-LOTI.html

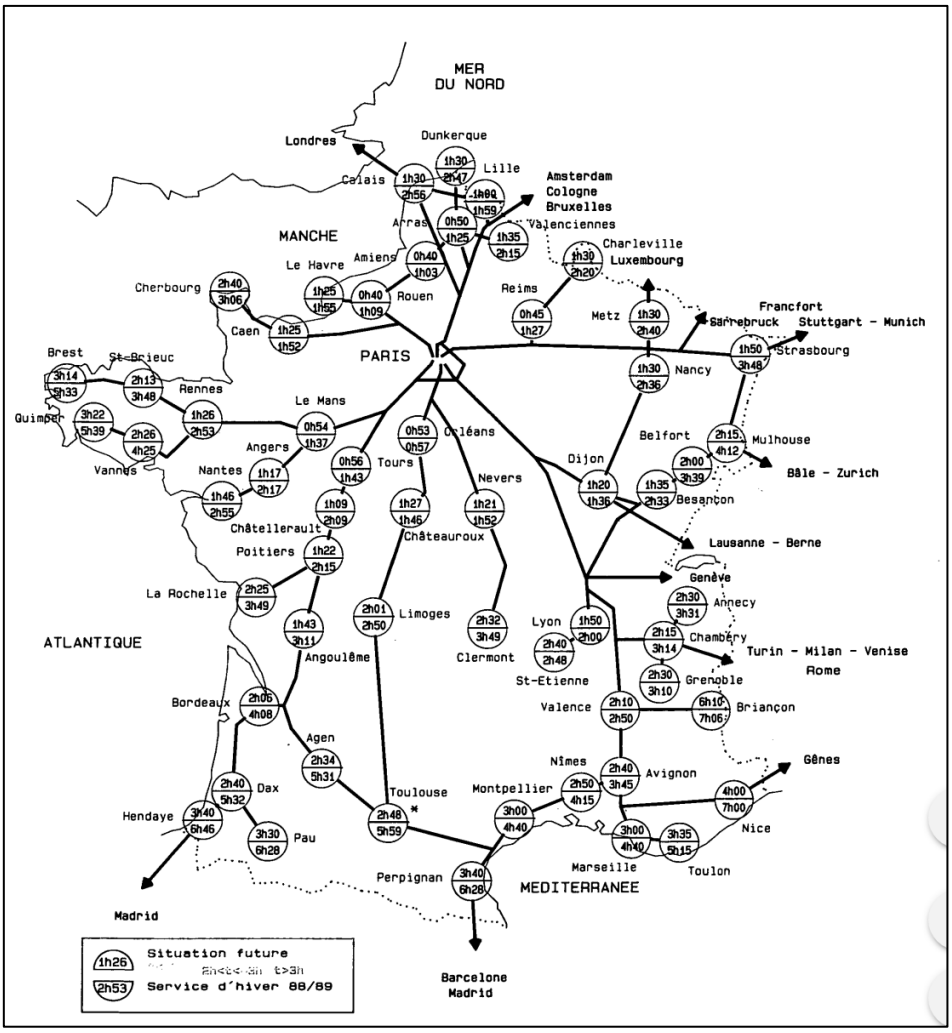
Master planning was less successful in developing waterways and completing the high-speed rail network as envisaged in successive plans which now appear unlikely to be feasible. The 2007 financial crisis triggered postponement of most of the planned projects and traffic is forecast to be too low to show sufficient returns to operate without subsidy. The crisis prompted consolidation of the sectoral master plans into an ambitious national transport infrastructure plan (SNIT) followed by a sharp retrenchment after a Parliamentary report "Mobilité 21" and reprioritisation of projects based purely on economic return.

Despite its shortcomings, the high-speed rail master planning process has provided a very useful degree of direction to infrastructure planning. The routes for the lines built and currently under construction were all identified on the original plan, and successive iterations have built coherently on this foundation. By and large the lines with the strongest economic case were built first. The process is also flexible enough to incorporate new links not originally foreseen. Although there have been attempts to add lines to suit incumbent politicians over and above the national interest, as reflected in net present value (NPV), none of these has yet been constructed.

The master plan has also facilitated agreements between central, regional, and local government on funding investments. For example, the extension of the Atlantic high-speed line from Tours to Bordeaux is part funded by local and regional governments south of Bordeaux on the understanding that further extensions will follow to Toulouse and on to Narbonne on the Mediterranean coast and to Dax/Bayonne on the Atlantic coast. The level of agreed funding was made on the further understanding that the Region of Aquitaine where Bordeaux is located will contribute to these extensions. Given growing doubts over the viability of extending the network further and Ministers proposing the extensions are delayed because of fiscal constraints, a number of the local governments have reneged on their contributions to the

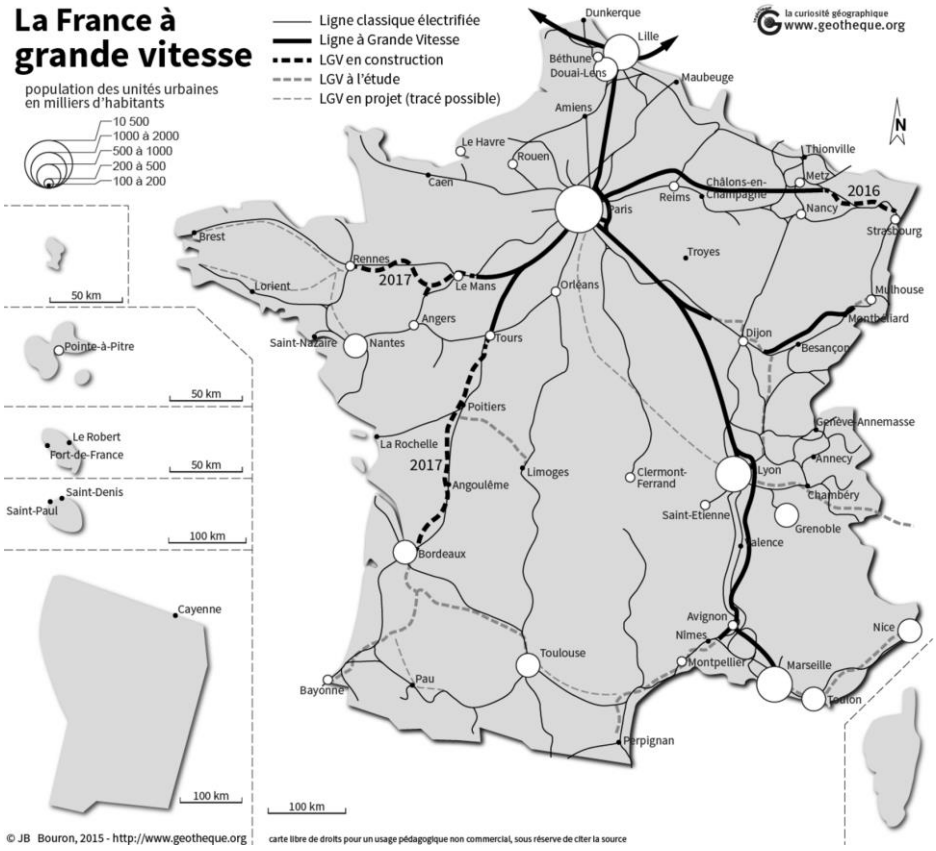
extension to Bordeaux. This and a shortfall in the funds available from the Agency for Financing Transport Infrastructure in France (AFITF) forced SNCF to raise additional debt finance. Nevertheless, negotiations continue between the regions over their shares in the financing of the extensions to the south and the AFITF agreed to fund preliminary studies on the Bordeaux-Toulouse and Bordeaux-Dax lines in December 2016.

Figure 7. **High-speed rail master plan (1991)**



Source: Décret n° 92-355, 1 April 1992.

Figure 8. **High-speed lines (2015)**



Key to lines: conventional; high speed; under construction; in planning; projects

Source: La Géotheque http://geotheque.org/carte-la-france-du-tgv/

Declarations of public utility

A very important stage in the planning and delivery of new transport infrastructure in France is securing the "declaration of public utility" (known as the DUP). In order to secure a DUP for a project, its socio-economic profitability needs to be assessed by conducting a cost-benefit analysis (CBA) developed by the Ministry of Transport. The CBA currently takes into account not only monetary costs and benefits, but also monetises the value of time gains for passengers and various external costs and risks. In addition to the CBA, the project has to be consulted on with different stakeholders. The consultation is based on impact studies that have gradually been enriched, particularly for potential impacts of transport projects on the environment.

Securing a DUP is an important necessary condition in planning new infrastructure development, but it is not sufficient – financeability of the project needs to be demonstrated as well. It is not uncommon that a DUP for a project is approved, but the project's delivery is put on hold because financing has not been secured. This is particularly the case with the most expensive projects, notably with high-speed lines.

A good way of ensuring a project's funding is to make users participate directly. This was done with toll motorways, but also with high-speed lines. High-speed rail is considered a commercial activity. The rail tolls of the high-speed lines should therefore, like motorway tolls, cover the complete costs of the infrastructure. Cross-subsidies between profitable and non-profitable sections were possible, and sometimes necessary. The success of the former master plans was, in part, due to infrastructure costs being covered by tolls from motorways and high-speed rail. However, since 2000, this is less valid for new projects and cross-subsidisation has also been forbidden for new motorway sections.

The "user pays" principle is still applied. The principle may have helped protect the decision maker from the ad-hoc politically motivated projects with low or negative rates of return and it ensures significant revenue. The TGV high-speed trains pay EUR 2 billion in tolls annually, equivalent to two-thirds of the infrastructure operator's commercial revenue. For toll motorways, the annual turnover is almost EUR 9 billion, of which a little more than 40% ends up in the state's coffers via various fiscal or social contributions. Pricing is therefore at the heart of the French interurban transport infrastructure programming and funding strategy, including in the form of cross-subsidies between different modes. A part of the revenue derived from the privatisation of the motorway operating companies in 2005 was thus allocated to the financing of rail transport infrastructure.

At the end of the 1990s, changes were necessary in the transport infrastructure programming and financing process due to new constraints that had to be taken into account.

The first constraint stems from the fact that France is already a well-equipped country in terms of its infrastructure. The new motorway sections or new high-speed lines demanded by local officials are compromised by low profitability, or even by negative net present value (NPV). Their construction therefore implies significant contributions from public purse in addition to that of the users.[9] Although securing public financing has been increasingly difficult, there are many projects currently proposed whose costs are not offset by significant economic or environmental gains as demonstrated by low or even negative NPV. The government developed a new set of rules for project selection and prioritisation, to account for the new financial constraint. In 2005, it introduced into the benefit-cost calculations an opportunity cost for public funds that reduces the profitability of projects that take a lot of investment subsides. At the same time, it defined an indicator enabling projects to be ranked in descending order of profitability: NPV by public euro invested. The transition towards a "sustainable" approach to transport infrastructure programming remains incomplete.

General Commissariat for Investment and the Grand Paris Express Project

The General Commissariat for Investment (CGI), created in 2010, must give its agreement for all large national projects. For example, it has just delivered a critical opinion on certain lines of the Grand Paris Express Project. The project has had a long and gradual gestation. The State produced the first master plan for the Paris region in 1965 (the *schéma directeur* for development and urban planning of the Paris region, SDAURP). A s*chéma directeur* for the Ile-de-France was prepared in the early 1990s, envisaging orbital metro lines in the suburbs. A number of proposals were subsequently developed independently by local mayors and the metro operator.

In 2009 the government of President Sarkozy proposed one transversal and two orbital high-speed, automated metro lines. The primary objective was to link the centres of finance, business, and education with the suburbs. This was in an effort to increase the attractiveness of Paris for inward investment and to increase productivity in the region through better access to jobs and better job matching. After extended stakeholder consultation elements of the plans were combined, prioritising lines serving lower income

communities for development ahead of the more economically viable transversal line that will link Paris' two airports to the centre of the city and to science parks to the south west.

Addressing the shortage of affordable housing also became an important objective, although development of property around the new stations was intended to cover part of the cost of the project. This funding approach was subsequently dropped. The project was included in the National Transport Infrastructure Plan (see next section). The extended stakeholder consultation, notably accommodating the mayors of less affluent suburbs east of Paris, generated cross-party support that saw the project survive both the financial crisis and the change of President and governing party.

National Transport Infrastructure Plan

Environmental considerations pose another set of constraints on transport infrastructure planning. The threats and uncertainties linked to climate change are reflected in aspirational targets set for the transport sector in the European Union's 2011 White Paper: transfer onto rail or waterways 30%, then 50%, of goods traveling more than 300 km; triple the length of the European high-speed rail network; and develop public transport capable of competing with individual cars in urban areas, etc.

Faced with these new constraints at the end of the 1990s, master plans created by transport mode were replaced by collective transport service plans. Established by the State in close consultation with the regions, they aimed to develop a multimodal approach, more focused on providing better service than on the ambition to develop new infrastructure. This was without counting on "peripheral power". During the change of political majority in 2002, intense lobbying by local elected officials led to the AFITF being set up in 2004. It was supposed to be sustained by the profits of the motorway operators, which were majority-owned by the State at the time. The motorway revenues were going to enable the Agency to free itself of the scarcity of public funds while being consistent with the goals of the European Union's White Paper, since the majority of projects to be financed were rail (high-speed line and freight[10]).

The National Transport Infrastructure Plan (SNIT)[11] was adopted in 2009 within the framework of a comprehensive new environmental law known as the "first environmental Grenelle law".[12] The SNIT listed 20 new high-speed lines (over EUR 100 billion), 49 motorway projects (EUR 24 billion), nine rail freight projects (EUR 5 billion), three waterways projects (EUR 21 billion) and eight port projects (EUR 2.5 billion). Behind the screen of a modal shift, the passion of local elected officials for building infrastructure prevailed.

Mobilité 21 and the current strategic planning environment

The SNIT was short-lived. Complete privatisation of the motorway operating companies in 2005 deprived the AFITF of its long-term resources and the election of a new President led to the implementation of new planning objectives in 2012. The 1Mobilité 21 Commission comprising ten members (six parliamentarians from across the political spectrum and four experts) was established to provide guidance that would outlive the electoral cycle and has succeeded in achieving cross-party support. The Commission made its Long-term National Sustainable Mobility Plan, which was approved by the government, public in June 2013.[13] It ranked infrastructure projects into three groups in descending order of priority, under two scenarios, optimistic and pessimistic, based on different economic growth projections:

1. First priority projects for implementation in the period 2014-2030, feasibility studies to be pursued with a view to implementation before 2030.

2. Second priority projects envisaged for the period 2030-2050, with feasibility studies to be pursued.
3. Projects with a planning horizon beyond 2050 for which feasibility studies should be halted so long as no new factors arise to justify taking them up again.

For the weak economic growth scenario, which has played out since 2012, no high-speed line was ranked among the top priority projects. Nevertheless, politicians continue to promote high-speed lines with voters in the provinces. Decentralisation of funding for high-speed lines a decade ago, with local and regional governments required to make a contribution to investment costs was designed to moderate demands for new lines but seems instead to have increased the number of proposals for unprofitable links. With access to EU funding a substitute for constrained national public funding, two costly projects of highly debatable economic value are about to be launched: the high-speed rail tunnel between France and Italy (EUR 9 billion, of which EUR 2 billion will be covered by the national budget) and the Seine-Nord Europe canal (EUR 5 billion, of which 60% will be covered by the national budget).

In December 2016 the Secretary of State for Transport convened a conference (*Mobilités et Transitions*) to discuss the conclusions of Mobilité 21 and the potential of new mobility services to change demands on infrastructure. He announced the intention to renew the Mobility report every five years. Given its broad cross-party support, the current report will likely form the basis for a national master plan for sustainable mobility for the government to be elected in 2017.

Between 2014 and 2016, in an effort to cut the overall cost of government, regional government was reformed in stages by merging a number of regions. This had an impact on transport funding. Responsibilities for funding road investment were modified, with local government only retaining responsibility for the lowest category of local roads whereas responsibility for all other roads, apart from concessioned motorways, was apportioned to the regions. As a result, it is expected that the Master Plans for Regional Economic Development will include transport infrastructure and logistics in the future which should improve cross-sectoral integration.

Strategic regional cross-sectoral planning: The Oresund Fixed Link between Sweden and Denmark

Sweden's planning experience underlines the importance of building cross-party support and highlights the role of an independent commission in creating the political space for sufficient consensus. The Oresund Fixed Link case of planning across two countries also demonstrates how forward-looking planning coupled with other policies to stimulate economic growth can achieve improved welfare outcomes.

The Oresund Fixed Link, connecting Copenhagen and Malmö by road and rail with a bridge and tunnel across the straights between Denmark and Sweden, opened in 2000. Construction of a bridge or a tunnel had been discussed by the Danish and Swedish governments at intervals since the 1950s, with the municipality of Malmö as a strong supporter of the project (UCL, 2015). An agreement to build a link was signed between the two national governments in 1973, but progress was suspended by the oil crisis and Denmark's decision to join the European Union. In the 1980s the plan was revived, in part by a report of the European Roundtable of Industrialists, established to promote growth through infrastructure investment, and their report on missing transport links. This highlighted the need for the Channel Tunnel and a Scandinavian link to Europe. Social democratic governments in both countries took up the proposal despite a divergence of views on the merits of the project in both parties. Overall the Danes favoured a rail tunnel while most Swedish politicians favoured a road bridge.

In Sweden, dissatisfaction with the planning process for major infrastructure had built up over the 1970s and 80s. Achieving consensus required very long periods of negotiation between political party leaders and local governments to adopt, in particular, transport plans put forward by civil service planners. Politicians naturally sought to promote only those plans that benefited their constituencies resulting in lengthy periods of negotiation and unpredictable outcomes.

In 1990 the Government appointed three negotiators for the Stockholm, Gothenburg, and Malmö regions to work with local governments to build consensus on packages of measures to improve the environment, improve accessibility, and support economic growth. For Stockholm the former head of the Bank of Sweden, Bengt Dennis, was responsible for recommending a controversial package of ring road investments and metro extensions that paved the way for the introduction of the congestion charging for central Stockholm. For Malmö the negotiator was Sven Hulterstrom. This appointment provided the time needed to resolve differences on the Oresund project related to rivalries between factions of the ruling party more than the project itself.

In Denmark the Social Democrats left office but cross-party support remained an important condition for advancing the project and a number of conditions were laid down by stakeholders in each country. The Danish political consensus was based on a condition that a rail link across the Great Belt, linking Copenhagen to Jutland should be built first, and this was completed in 1997. This coincided with the views of the Swedish Rail Administration which saw the onward rail link through Denmark to Germany as essential to the success of the project. The Swedish Environment Agency found unacceptable impacts on the natural environment, but the Government ruled its findings non-binding.

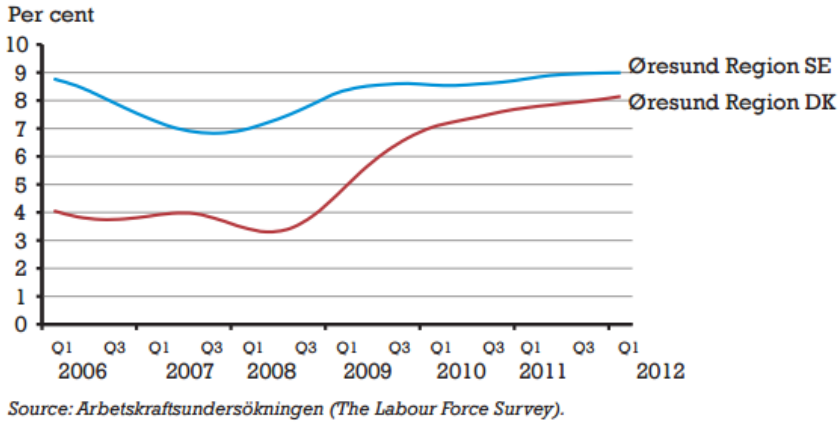
The financial aspects of the project were also subject to constraints. Danish interests sought to preserve the competitiveness of the existing ferry operators and the two governments agreed that prices for using the link should take ferry charges as the lower bound constraint. Denmark further required that the project should be self-financing, whilst Sweden wanted it to be publicly funded. The result was the creation of a State-owned company to manage the project, structured like a public private partnership, but entirely with public funding. This was effective in delivering the project on time (although with a 30% cost overrun attributed mainly to environmental planning risk). The strategic planning and governance framework for the Oresund link was institutionalised by the establishment of an Oresund Committee in 1993, renamed the Greater Copenhagen & Skåne Committee in 2016. It comprises the local and regional government administrations on either side of the link, joined by the National governments in 2006. The Committee published its Regional Development Strategy (ORUS) in 2010, with a focus on integrated land use and transport planning. The plan targets developments to 2020 aiming to revive the growth stimulated by the Oresund project that had attenuated in the meantime. The strategy focuses on stimulating investment in high-tech industry and the knowledge economy, but has been criticised for lacking detail in comparison to earlier plans.

Building the fixed link was part of a broader strategy to establish the Oresund as an integrated region and increase productivity through agglomeration and an integrated labour market, the emphasis was on developing a European scale science and technology cluster through parallel investments in universities in Copenhagen and Malmö based around the “Medicon Valley Alliance” of pharmaceutical and other bio-tech companies (around 50) located in the area. The international connectivity provided by Copenhagen Airport is a key part of the strategy.

Opening of the fixed link saw a rapid rise in commuting from Sweden to Denmark, driven by differences in property prices between the two countries. Many Danes relocated to the Malmö region while continuing to work in Copenhagen with its higher salaries. Full employment (3-4% unemployment) on the Danish side of the bridge with 9% unemployment on the Swedish side also drew

Swedish workers to commute to Denmark as the Danish economy boomed in 2005 (Oresund Trends, 2012).

Figure 9. **Oresund region unemployment trends in Sweden and Denmark**



Source: Oresund Trends (2012).

The labour market effects alone are estimated to have generated gross value added in the Danish market and unemployment benefit savings on the Swedish side of the link equivalent to 150% of the cost of the project over its first 12 years of operation (Oresund Trends, 2012). UCL reports a benefit-cost ratio of 2.2 with an internal rate of return of 9% calculated over a 50 year lifespan with over 70% of benefits related to the labour market.

A similar project is currently being jointly developed by Denmark and Germany – the Fehmarn Belt rail link. The link, which will shorten travel time between Copenhagen and Hamburg, is to be built under the same project management structure as the Oresund link.

Infrastructure planning in Japan

Post-war Japan has gone through a series of socio-economic shocks and is suffering from two decades of economic stagnation coupled with an ageing and shrinking population. Over the years, infrastructure policy has shifted from a doctrine of build for development to a focus on outcomes. The focus on outcomes was reflected in the development of the necessary appraisal tools in the late 1990s and creation of a framework for private finance initiatives.

The response to diminishing returns on investment in new high-speed rail lines in peripheral areas was to remove responsibility for financing such lines from the commercial high-speed train companies. The Government is funding extensions to high-speed lines in a number of such areas with the objective of stimulating tourism and related investment in hotels. Decisions are based on considerations of regional equity not direct economic returns. Like in France, the other major development in Japan's strategic planning is the replacement of sub-sectoral transport master plans with a multimodal approach.

National Public Infrastructure Investment Planning

The first "Comprehensive National Development Plan" was delivered in 1962 based on a Comprehensive Land Development Law of 1950. Amid rapid post-war industrialisation the plan aimed to achieve a balanced spatial development of manufacturing industry by promoting multiple industrial cores around the nation. A series of ten-year national land development plans was subsequently delivered

in 1969, 1977, 1987 and 1998. Although emphasis with time shifted from industrialisation to improvement in environmental protection and safety, re-balancing of spatial concentration has stayed at the top of the agenda. In 2005, the Comprehensive Land Development Law was revised to become the National Spatial Strategy Law, shifting the emphasis from regional development to strategic guidance of investment. The current strategy, for the years 2015-2025, has an emphasis on facilitation of "interaction between regions" in an era of declining population. The strategy is based on a policy paper "National Grand Design 2050" prepared in 2014 by the Ministry of Land, Infrastructure, Transport and Tourism (MLIT).

Five-year plans for specific sectors, introduced in the 1950s to facilitate infrastructure planning, were produced and implemented directly by central and local governments. For instance, the Five Year Airport Construction Plan, initiated in 1967, was followed by six additional plans delivered in sequence, the last of which was for the period 1996-2000.[14] But not all infrastructure sectors saw the development of five-year plans. For example, infrastructure sectors such as rail and electricity were out of scope of the planning framework since they were vested in the hands of public agencies and private firms.

As economic growth peaked in the 1980s, infrastructure demand began to level off and by the end of the 20th Century the output oriented five-year planning approach had become obsolete. At the same time the collapse of asset bubbles in the mid-1990s led the government to resort to public investment, particularly in rural areas, as a means to stimulate the economy. Since then the emphasis has been placed increasingly on value-for-money and outcomes, with a more multimodal perspective. Environmental factors including global warming and disaster prevention have also become prominent.

In 2003, a Priority Plan for Social Infrastructure Development was adopted. The plan called for integration of the nine sectoral long-term infrastructure plans. The first such comprehensive plan, for the years 2003-2007, was adopted in a context of fiscal constraint with stagnant economic growth. As the Ministry of Finance explained in a note on the budget for 2003,[15] policy towards investment in public infrastructure (roads, ports and harbours, housing, water supply and sewerage, and river embankments and dams) has been defined as catching up on other western economies, estimated to have a larger stock of assets relative to the size of their economies. The current plan[16], the fourth edition covering the period 2015-2020 adopted in 2015, has four major objectives with target KPIs:

- strategic maintenance and renewal
- reduction of risks from natural disasters
- regional sustainability under conditions of a declining and aging population
- inducing private investment and facilitating economic growth.

Investment in new transport infrastructure has become more focused on strategic assets for national competitiveness. Despite its focus, quantitative ex-post economic assessments of the effectiveness of public investment and the output generated produced inconclusive results particularly for projects in rural areas.

Railway planning, investment and restructuring

The first railway in Japan between Tokyo and Yokohama was constructed by the government in 1872. A number of lines that followed were funded by private capital. These railways were mainly constructed in urban areas for commercial returns generated from associated development of retail services and housing around the stations. The basic principles for State initiatives in trunk rail line development were set out already in the Railway Development Act of 1892. In 1906, the majority of the

private railways were nationalised and 90% of the total network came under direct control of the government. In 1949, the national railway network was vested in the hands of the Japan National Railway (JNR), a state-owned enterprise.

The JNR was given a mission to ensure all parts of the country were accessible for industrial redevelopment. The organisation was also required to absorb a very large number of veterans returning to the labour market after the war. Neither this influx of staff nor the public service mandate to support regional development was compensated with public funds. The debt of the organisation thus became unmanageable by the early 1960s with the company falling into the red in 1964 (Kasai, 2003). Urban sprawl and motorisation exacerbated the financial deterioration of local railways in the 1960s and freight rail lost to extensive motorway development. As construction of new high-speed rail routes proceeded despite the debt accumulation, the financial problems of JNR worsened and new route construction was stopped in the mid-1980s. As a result, the organisation was split into six passenger firms and one freight firm in 1987. The three largest passenger firms were listed on the stock market during the 1990s. Following the 1987 reform, high-speed rail infrastructure was owned by a government agency and leased to Japan Rail (JR) firms, until 1991 when it was sold back to the relevant JR firms. The sales of the infrastructure and subsequent IPOs of the JR firms provided the financial resources for the government to restart construction.

In 1996, a new public investment scheme for high-speed rail was introduced, funded two-thirds by the central government and one-third by the local governments, in addition to payments for infrastructure use corresponding to the marginal benefits to JR firms of operating trains on the new lines. Local governments were also required to maintain existing railways negatively affected by the new Shinkansen routes. This scheme has been applied to the remainder of the section stipulated under the Construction Plan delivered in 1973. Appropriation of funds to these projects has been and still is highly political, with a pay-as-you-go rule serving as a constraint. The total annual budget of the Shinkansen extension projects has been composed of two parts: the annual government budget appropriation, which is predominantly anchored to a specific level over time, and pre-fixed dues from sale-back of original Shinkansen assets and lease revenue of newly developed Shinkansen routes from privatised national railway firms. Lessons learnt from JNR reform have led the government to follow this de facto pay-as-you-go rule and avoid relying on loans to fund national railway investment.

Ex-ante cost-benefit analysis and ex-post appraisal is now mandatory for public investment in infrastructure. Ex-ante appraisal relies on CBA conducted in a partial equilibrium setting and there is some use of computable general equilibrium and land-use model simulation to supplement it in appraisal although these tools are not mandatory. Quantitative ex-post macroeconomic impact assessment is still in its research phase. Experience in the use of project appraisal is too recent to draw conclusions on the value of the publicly funded high-speed rail extensions.

Strategic infrastructure planning: Account for uncertainties and interdependencies

The discussion of infrastructure planning to account for uncertainties and interdependencies identified two routes to future-proofing infrastructure investment:

- fostering stakeholder engagement
- developing tools for analysing the need for infrastructure that explicitly address uncertainty and risks, particularly financeability issues, as well as interdependencies between different sectors of economic infrastructure.

Stakeholder engagement

Stakeholder engagement is crucial to a successful infrastructure planning exercise. Not only does it serve the purpose of adding credibility to the exercise, but it also creates an important venue for learning about potential supply-side changes by enabling the policy maker to learn about business models and technological change in the private sector.

Openness and transparency are guiding goals for all government departments in the UK and are seen to potentially save money; strengthen people's trust in government; and encourage public participation in decision-making.[17] In that spirit, for example, the Airports Commission engaged openly with a wide range of stakeholders through formal consultations, and a programme of meetings and visits. That helped the Commission build support for its approach and recommendations. Moreover, involving a wide range of stakeholders offered insights and perspectives that might have otherwise been missed.

In Japan planning and decision making is generally characterised by a gradual process of building consensus through recurring discussions between government and industry stakeholders.. More recently, a highly representative and transparent process of stakeholder consultation was developed for the decision on where to locate the new international airport in the Kansai (Osaka) region. In 1971 the Minister of Transport commissioned the national Aviation Council to scrutinise the "size and location of Kansai International Airport." A Kansai Airport Committee was established for the task, composed of seventeen members including university professors, aviation experts, industry representatives and mass media journalists. Government representatives including from the Environment Agency, Fisheries Agency National Land Agency, Ministry of Finance, Ministry of Internal Affairs and Ministry of Construction also participated. Consultations began by announcing that no time limit would be set for that process. A total of twenty-nine committee meetings, eleven Sub-committee meetings and six informal meetings were held before the Committee's report was submitted three years later in August 1974.

Such consensus building, however, is not always the case. For example, the first high speed rail Shinkansen line was only built because a consensus among senior railway management and government officials to instead upgrade the conventional rail network was over-ridden by a small dissident group of engineers and managers who gained political support for the project

France has developed an effective consultation process for major transport infrastructure investments following problems with the acceptability of motorway projects and later high-speed rail

lines. The approach was initially built around provisions of a 1993 law to protect landscapes and biodiversity (*Loi Paysage*) that among other things provided for compensation to communities adjacent to motorways subject to noise, visual intrusion or severance nuisance and too far from junctions to benefit much from the new infrastructure. Funds equal to 1% of the overall cost of projects are required to be set aside for this purpose with negotiations organised with local community mayors to determine appropriate compensatory investments in masking the infrastructure or supporting economic or cultural development in the communities concerned.

The extensions to the Atlantic high-speed rail line illustrate the system today. The Tours-Bordeaux project involved 150 public meetings to provide information on the project from its very earliest stages and 2 000 stakeholder consultations. 500 visits to four construction sites were organised, principally for local residents, with nearly 20 000 people attending over a period of three years. Consultations resulted in modifications to the route of the line and improvements to roads in the neighbourhood of the line. They also resulted in 10% of the construction jobs on the project being reserved to local people on job creation programs and 10% of the value of construction contracts being sub-contracted to local suppliers. Stakeholder consultations also resulted in agreements on environmental protection, avoiding sensitive sites, and creating natural environments close to the line in compensation for comparable sites disturbed or destroyed.

Table 5. **Key decisions for the high-speed rail line Bretagne-Pays de la Loire**

Date	Step
1994-1995	Initial debate
1996-2001	Preliminary studies
2002-2005	Feasibility studies
2006, January	Ministerial approval of the summary feasibility study
2006, June-July	Public inquiry for a declaration of public utility
2007, January	Agreement between the State, railway and local authorities on the stations to be served by the new line: Le Mans, Laval, Vitré, Sablé sur Sarthe.
2007, October	Declaration of public utility, issued by Decree of the Council of State
2008, July	Agreement on the project between the State, the Regions of Brittany and the Pays de la Loire and the rail infrastructure manager (RFF)
2009, January	Statement of commitments by the State
2009, July	Agreement on protocol for financing the project between the State, the Regions of Brittany and the Pays de la Loire and RFF
2011, May	Declaration of public utility for the spur at Sablé sur Sarthe for services to Nantes
2011, July	Agreement on financing the spur
2011, July	Signature of PPP contract between RFF and Eiffage Rail Express
2011, August	Decree approving the PPP
2017	Entry into service of the line

Source: SNCF Réseau, http://www.bretagne.bzh/upload/docs/application/pdf/2012-09/plaquette_aout_2012_bat_hd.pdf

The consultations with the biggest potential impact were those with local and regional governments in negotiations over funding of the project (see above). This centred on demands for stations to serve intermediate points on the route. In the end no new stations will be built, but spurs will serve four intermediate stations. The results of the stakeholder consultations are presented in some detail by the project promoters in a series of magazine type newsletters "LISEA Express".[18] Stakeholder consultations form part of the formal decision-making steps required ahead of construction. These are summarised in Table 5 for the other extension of the Atlantic line currently under construction, from Le Mans to Rennes. This project includes upgrades to conventional lines beyond Rennes along two routes serving the west of Brittany and a branch south to Nantes at the mouth of the Loire river. The phases of decision-making are representative of all major infrastructure projects.

Addressing uncertainty through scenario-based planning

Infrastructure planning is becoming increasingly complex. As the predict-and-provide approach to planning becomes increasingly obsolete, decision makers need to deal with a multi-layered decision-making framework. This combines making decisions on investing in new infrastructure with how to manage scarce capacity, while taking into account any potential efficiency improvements due to new technological options.

Apart from the need for creating a "big picture" framework for analysis discussed in the next section, the experts stressed the importance of addressing uncertainty at all stages of infrastructure planning and particularly in the:

- Assessment of need for infrastructure investment: How to address uncertainty in long-term forecasts of demand for infrastructure?
- Assessment of potential options to meet the need: How to address uncertainty when developing cost-benefit analysis of different projects?

Any strategic decision over a long-term horizon needs to be based on credible forecasts of demand. But predicting the future is impossible and forecasting is a demanding task – forecasts are underpinned by a number of assumptions, for example around domestic consumption, trade with other nations, population growth, continuity in technological improvements (for example with respect to decreasing CO_2 emissions from transport), business models of suppliers of how transport, energy, and water are provided. Forecasts also make certain assumptions with respect to the regulatory regime and government policy. The multiple global trends driving the need for infrastructure including the direction and speed of technological progress make prediction impossible.

Infrastructure planning across sectors adds complexity to the planning exercise as it requires dealing with interactions and interdependencies within the entire infrastructure network. But it also presents an opportunity – rather than evaluate projects by themselves, infrastructure can perhaps be more effectively looked at in a context. In other words, project evaluation performed across sectors can move away from projects to analysing the efficiencies and interdependencies from multiple assets.

Young and Hall (2015) propose that the interdependencies between projects can be represented as pathways. Each pathway can be then evaluated based on four attributes: environment (air quality, carbon dioxide emissions, habitat loss/creation, landscape/visual amenity, noise and water quality); social (safety and security); service (utilised capacity, congestion/reliability and physical protection); and financial (cost, revenue, tax implications and employment). The four aggregated attributes are evaluated for each year of the appraisal period and then the benefits are evaluated relative to a baseline investment path. Finally, pathways are grouped into families according to the assets implemented, with the appraisal results reported against these family groups. The most common approach to addressing uncertainty

relating to the forecasts of demand is through developing scenarios. Due to its exposure to many global and local risks, a scenario-based planning approach was pioneered by the oil industry (see Annex I). It is an attempt to better understand the uncertainties surrounding the decision-making. And perhaps the greatest value of conducting this process is in assessing risks and taking stock of potential uncertainties, which generates valuable discussion and better understanding of the range of possible outcomes. The discussion of the use of scenarios in the private sector was based on a presentation by Henk Krijnen who contributed to this publication by authoring a paper which sets out how scenarios are used in a private-sector setting (see Annex I). The practice of testing decisions against a broad range of scenarios developed initially in the oil industry is now also routine for many governments.

The experts discussed what principles should be followed in order to ensure that scenarios are set out correctly. The scenario-based approach to forecasting aims to reduce the complexity of the external environment to a few internally consistent logical concepts that will let decision-makers understand which factors drive outcomes relevant to the question they are asking and what the potential impacts of different uncertainties materialising may be. The participants agreed that the number of scenarios developed should not be too large, ideally not larger than four. That, however, is not the only way of developing scenarios. For example, Lempert et al. (2003) offers an alternative for generating scenarios through computer simulation of millions of different futures. Each of the scenarios should be guided by a persuasive and plausible narrative, and each needs to be internally consistent. The scenarios should also be dynamic: If a vital piece of new information becomes available about any of the drivers, the scenarios should be updated and the decision should also be reviewed in light of new evidence.

Addressing uncertainty through a scenario-based approach is a well-known and widely used method of enhancing credibility of valuations. As a method it still is not, however, very popular with policy makers. According to the participants, one of the reasons for this is that policy makers face multiple objectives and need to make trade-offs between many different aspects of their decision-making – for example, economic growth against environmental impacts, while companies are largely focussed on only one objective which is profit maximisation. Scenarios developed for policy makers may then need to cover too many factors and become too complicated to communicate easily.

Scenarios can help the decision maker devise a few investment packages with different levels of ambition (i.e. scenarios assuming strong economic growth will allow for more resources to be spent and for more projects to be delivered). Which package gets delivered will depend on the future economic conditions. Such “optioneering” strategies are currently used in France. There is also the issue of how a scenario-based approach fits with project appraisal. The participants pointed out that creating scenarios is a helpful way of considering risks and uncertainty and it also allows policy makers to test whether a project is robust against different possible states of the world. But they also pointed out that scenarios may create too much noise in the economic appraisal of different infrastructure investment options. An open question remained with respect to how to apply the scenarios used for conducting the assessment of need for infrastructure investment in the actual appraisal of different options and how they could meet that need. There was consensus that scenarios would serve as a useful background in the appraisal process, but there remains a methodological discussion to be had with respect to how to apply scenarios to different appraisal modules.

Among the challenges to a scenario-based approach the participants mentioned that scenarios are usually biased by the “flavour of the day”. The experts also agreed that scenarios cannot offer a direct path to decision-making, but can be a useful tool to analysing the limits of different proposals. For example, scenarios can test what the worst possible environmental outcome of an infrastructure development could be by making assumptions on high economic growth projects and certain

CO_2-intensive business models to be used. Another example would be a pessimistic scenario to test how low numbers of users would translate into the financial viability of an infrastructure project.

One of the participants asked how good the scenario-based approach would have to be in order to shed useful light on long-term planning of infrastructure. The response was that it is impossible to have expectations that one of the devised scenarios will "hold true" in the future (or that it is the "correct" one). That is not the purpose of setting scenarios.

The experts discussed scenario-based infrastructure planning in several different countries, noting that it is quite common to use scenarios for testing risk and uncertainty with respect to demand projections. In contrast, it is quite uncommon for the planning exercises to test the costs and benefits of short-listed projects against different potential states of the world, in order to investigate how robust they would be in different potential versions of the future. The experts agreed that strategic infrastructure planning needs to include such testing in order to help ensure resilience of the infrastructure network in the future. The experts thought that it was important to stress that such an approach moves policy making away from looking for an optimal solution (i.e. a solution maximising welfare in one future or a central-case scenario) to a new territory of looking for a robust solution (i.e. a solution that is most likely to perform well under different states of the world).

There are some exceptions. For example, in the UK the Airports Commission applied a scenario-based approach to assess the need for new airport infrastructure (for more information see Airports Commission, 2015). The Commission then used the developed scenarios to test the robustness of different expansion options across different potential states of the world. These states of the world were defined by different relative speeds of global socio-economic development, different paths of development of a global deal on carbon emissions from aviation, different possible ways in which the global aviation industry will adapt to these changes, and different input prices for the industry.

While the results achieved through application of scenarios generated important insights for the Commission when deciding between expanding airport capacity at two different locations, Gatwick or Heathrow, some experts noted that the challenge of this approach was with communicating and presenting results. The Commission developed five different scenarios, each of which was developed for two different assumed regimes on how carbon emissions from aviation might be treated in the future. Different appraisal modules at the Commission were then tested against at least two scenarios – the central scenario[19] and the most pessimistic scenario for each appraisal module. That way, the Commission got insight into what were the implications of the worst case scenario. This process was repeated in this or a more sophisticated form for all appraisal modules. It thus resulted in a plethora of numbers available for the decision-makers. In the end, for presentational reasons the Commission decided to use only the numbers estimated against its central scenario for the final report. This created confusion among some of the stakeholders on whether the Commission took all available evidence into account.

This example raises the question of how to strike the balance between setting out a process which considers all available evidence and testing this evidence to the extent possible against making the process helpful for the decision-makers and understandable to the wider public. Policy makers who apply scenarios need to carefully consider, on a case-by-case basis, which drivers and aspects of the problem they would like to test and for what reasons. With an increasing number of available techniques for estimating costs and benefits of infrastructure projects, there is more need than ever for developing new tools for communicating the results of complex deliberations to the public. Addressing uncertainty through developing robust scenarios (see Annex 1 for more details on methods) is the first step towards achieving that goal.

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Annex I. Uncertainty analysis for long-term decision making

By Henk Krijnen, NavIncerta

Decisions about investments that are meant to yield benefits in the long term in an uncertain future business environment require careful analysis. A simple deterministic economic cost-benefit analysis may be biased, as it does not account for uncertainties that are inherent in the underpinning assumptions. A probabilistic approach, where input assumptions are expressed in ranges rather than single numbers, is more meaningful, as decision metrics can be presented with their degree of uncertainty. In addition, the process of assessing uncertainty generates valuable discussion and a better understanding of the risks among decision makers and other important stakeholders. In many organisations, risk management is an established discipline. It is quite possible to augment the identification and management of risks by quantifying them, where relevant and credible. This allows integration of the residual risk assessment following from the risk management activities into the economic probabilistic analysis. Doing so will enhance the credibility of the valuation. Yet there may still be uncertainties related to the broader contextual environment that are not fully quantifiable. Such uncertainties may be described using a semi-quantitative scenario approach. It is best if links can be made to the decision criteria for the investment opportunity at hand. Economic cost-benefit analysis (CBA), probabilistic analysis, risk management and risk quantification, as well as scenario thinking, should be integrated and properly woven into a value proposition that provides maximum clarity to decision makers. The objective is to illuminate as well as possible the various types of risks and uncertainties that are associated with a particular investment opportunity and its benefits. But this will never take away the need for decision makers to exert sound judgement using their experience and intuition.

1. Definitions

Decision making can be a challenge even in the absence of risk and uncertainty. Consider the purchase of a new car for one's personal use. There are no uncertainties and no risks, provided sufficient funds are available. The need to replace one's current vehicle is obvious, the options have been identified, the associated prices are known. Everything is clear. Nevertheless, the ultimate choice will usually require much consideration: type, colour, accessories are to be reviewed, trade-offs made, stakeholders consulted. The challenge considered in this paper is that, in addition, many of the parameters or issues that influence the decision cannot be fixed or pinpointed at certain values or known attributes. They are uncertain. This is especially the case when the decision concerns a long-term investment project. This paper will explore ways to assess the boundaries of such uncertainties in order to provide a sound basis for decision making.

When considering uncertainty in the context of making large investment decisions, it is useful to have a framework: a set of principles for a decision process and the analyses to be conducted. The paper briefly makes reference to two such frameworks.

One is the decision quality concept, as formulated at Stanford University in California (e.g. Spetzler et al., 2016). It is used in industry, notably at oil and gas companies and pharmaceutical firms, but also elsewhere. The concept stipulates that a good decision is not synonymous with a good outcome. A favourable outcome of a decision under uncertainty may just be good luck. The quality of a decision hinges on six key requirements (Box A1).

Box A1. **Decision quality framework**

The decision frame constitutes the development of an overview of the key parameters for the decision. What precisely is being decided? What are the givens and boundary conditions? What are the uncertainties? What are the decision criteria?

The alternatives are necessary to develop multiple creative and doable options to choose from. This means not just focusing initially on a preferred solution but working out three or four sufficiently different viable designs or solutions.

Reliable and relevant information is an absolute must to understanding the potential outcome of each alternative. This will include assessing the degree of uncertainty within the information, or caused by lack of information.

Clear values describe preferences and need to be translated into decision criteria. It may not always be possible to express them in monetary terms. Decision makers need to make **trade-offs** between values to arrive at a final decision.

Sound reasoning integrates alternatives, information and values. A range of methodologies and processes can be applied, depending on the type of decision problem and degree of uncertainty: multiple attribute analysis, economic analysis, cost-benefit analysis, risk and uncertainty analysis, scenario analysis, etc.

Commitment to action: the organisation must be ready and able to implement the decision.

A recent in-depth treatment of the decision quality concept is provided by Spetzler et al. (2016). The decision quality concept is augmented with various decision analysis techniques and process descriptions for performing analyses and defining decision procedures; see, for example, Goodwin and Wright (2010) or McNamee and Celona (2001).

The other framework is RAMP (Risk Analysis and Management for Projects). It is a practical working guide issued by two UK organisations: the Institution of Civil Engineers and the Institute and Faculty of Actuaries. RAMP is a framework for analysing and managing risks in all kinds of projects, with an emphasis on strategic and financial aspects. As it focuses on civil engineering (infrastructure) projects, it is of particular relevance in the context of this paper. It is summarised in Box A2.

In both frameworks, due reference is made to the need to analyse risks and uncertainties, which is relevant for most major investment decisions. This paper provides an overview of the key relevant concepts for this purpose, including probabilistic approaches and risk management (as in RAMP), with emphasis on scenario analysis of the business environment.

This paper uses “uncertainty” to mean a variable or phenomenon with a range of possible outcomes, and “risk” to mean exposure to an undesirable outcome. The term “project risk” thus refers to the exposure to an undesirable outcome of a project. In economic terms this could be, for example, a result of negative net present value or a financial loss. Or it could mean that other project objectives are not achieved.

If one throws a die for the sake of it, the outcome is uncertain but there is no risk. Only if consequences are attached to the outcome, for example through betting, does the notion of risk come into play. Nevertheless there are various other interpretations and definitions of the words “risk” and “uncertainty”. In the financial world, risk is often used as an equivalent for range or standard deviation,

as related to the stochastic behaviour of stock and bond prices over time; uncertainty is then used in the context of bigger issues (political, societal, etc.) that are not quantifiable. Sometimes risk is interpreted as meaning an unfortunate event. For the purposes of this paper, however, risk is not an event per se but exposure to an undesirable event or development.

Box A2. **Risk analysis and management for projects**

Risk analysis and management for projects (RAMP) is a hands-on guide with practical checklists and detailed step by step process descriptions. Its advantage compared to the decision quality concept is that it also integrates risk management, a well-established discipline in many organizations, into the decision making scheme. It lacks, however, the crisp articulation and structure of the decision requirements as embodied in the decision quality concept. Of course, there are considerable overlaps as well.

RAMP has, roughly, the following components:

- requirements for good project decision making
- processes and phases for proper project maturation
- risk and uncertainty identification, analysis and management
- social and environmental risk, stakeholder engagement
- decision implementation.

For the full document, please refer to (The Institution of Civil Engineers and the Institute and Faculty of Actuaries, 2014).

Sometimes a distinction is made between technical and non-technical risks. Technical risks stem from uncertainties associated with the "normal" technical execution of an investment project: design issues, technical timing, normal cost uncertainty, the possibility of equipment failure. It is reasonable to assume that these uncertainties can be overseen by the project team or investor. While the project team does not necessarily have full control over all these risks, they are considered part of normal business. Non-technical risks can be seen as being related to issues that are caused or triggered by external stakeholders or third parties, e.g. communities, authorities, interest groups, business partners, etc. Non-technical risks relate to political, regulatory, commercial or community issues and the like. They are outside the investor or executing party's control, although influencing may be possible.

If a company or investor has a portfolio of investment opportunities, the distinction between systemic and idiosyncratic risk will be useful. Idiosyncratic risk is linked to an uncertainty for a specific investment opportunity or project. It could also be called project- or opportunity-specific risk. It relates only to that specific project: for example, a design or schedule risk, or a risk due to local circumstances. If you consider the total portfolio of projects, the overall impact of such risks is attenuated, but not eliminated. In some cases things go wrong; in other cases one may get lucky. Systemic risk is exposure to an uncertainty that will affect all, or a substantial number of, the projects or investment opportunities in a portfolio. Of course, such risks deserve specific attention by a company board. For a pharmaceutical company, for example, such a risk could be a regulatory issue. For an oil company, a key systemic uncertainty is the oil price.

There is also catastrophic risk, or exposure to severe events with major consequences, such as loss of large capital goods, a huge impact on the environment, or loss of lives: examples are explosions, severe weather, accidents, fires and mechanical mishaps. Often it is found that a catastrophic risk has

limited consequences for the economic value of an investment project because of its low probability, yet because of the potential impact if the catastrophe occurs, such risks are carefully considered in the decision making process.

Country risk refers to the risk associated with investing in a country with exposure to changes in the business environment that may adversely affect operating profits or the value of assets in that country. The term may capture a range of issues, although the most relevant dimension would be the political environment.

Although it is useful to distinguish different types of uncertainties and risks, there is no fundamental difference in the way they should be analysed and incorporated in value propositions. A practice that is sometimes employed is to incorporate the perceived overall risk associated with an investment opportunity, or with a country where the investment is planned (country risk), in the discount rate. Higher risk would translate into a higher discount rate, yielding lower calculated project value. The author believes, however, that this is not a meaningful approach. While a fixed corporate discount rate, based on the weighted average cost of capital, is a useful concept to account for the time value of money, differentiation based on country or opportunity risk is inappropriate and impractical. The most problematic aspect is that it lumps things together and discourages proper identification, quantification and mitigation of risks (NavIncerta, 2016).

Instead this paper advocates using probabilistic valuation techniques, including risk identification and quantification using a combination of historical data analysis and judgement. For uncertainties that are difficult to quantify, a scenario approach will be clarifying.

2. Probabilistic valuation

2.1. Rationale

Probabilistic valuation analysis provides a way to assess and aggregate the impact of project risks and uncertainties on decision metrics such as net present value (NPV) and capital efficiency indicators. Such analysis does not need to be complex. It yields improved insights for investment decision making and promotes a much better understanding of the risks and uncertainties through the rigour of quantification.

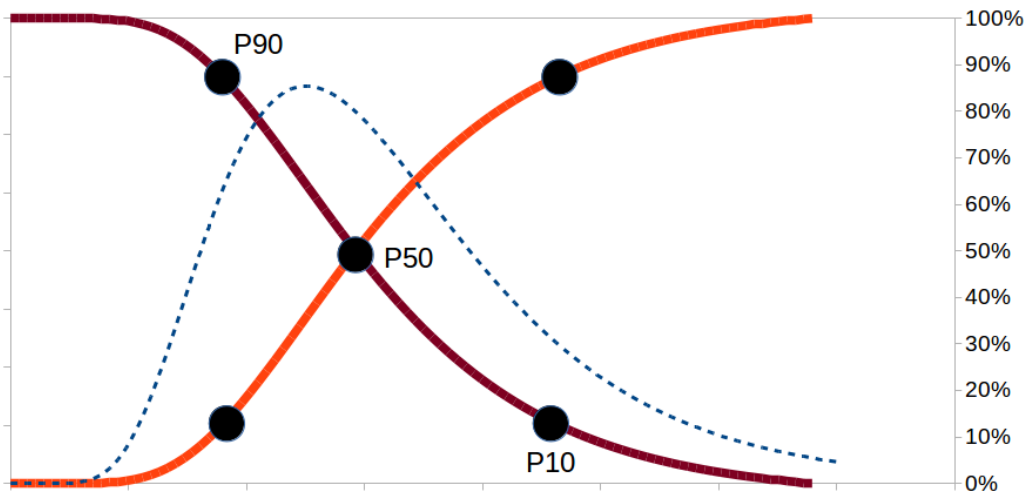
The fundamental characteristic of probabilistic economic analysis is that probability distributions are assigned to the input data (costs, sales volumes, prices, etc.), which are then aggregated, taking into account the valuation model. The classic deterministic approach is to develop a single base case with perhaps several sensitivities around it as examples of other outcomes using different sets of assumptions. However, the numbers that represent the base case are often biased. Although efforts will be made to include contingencies and make the base case a balanced representation, experience from industry suggests that the choices made are often optimistic. A key benefit of more rigorously assigning probabilities is that it consolidates the judgement of experts, yielding considered assessments of the uncertainties in the input data. A probabilistic economic analysis aggregates these uncertainty perspectives in a holistic view that allows interpretation of the overall uncertainty level in the decision metrics. It provides more nuance to the value proposition than only a “representative” base case.

Considering probabilities for the purpose of incorporating them in the economics or cost-benefit analysis also encourages teams to think carefully about the uncertainties affecting their project. Requiring them to quantify uncertainties leads to valuable discussion and better understanding of the risks.

2.2. Probability distributions

Often a variable such as a future cost or schedule item can assume a continuous range of values. Such a continuous uncertainty can be characterised by a probability distribution, defined by range and shape. Figure A1 illustrates the concept of a probability distribution. The variable in question is depicted on the horizontal axis. The blue dotted line is the probability density function, which can be interpreted as the smoothed, mathematical version of a histogram. The orange curve is the ascending version of the cumulative distribution: the vertical value is the chance that the variable in reality will turn out to be less than the point on the horizontal axis. The purple curve is the descending version of the cumulative distribution: the vertical value is the chance that the variable in reality will exceed the point on the horizontal axis. Often, a probability distribution is characterised by three values, using the 10th, 50th and 90th percentiles (ascending convention) or 90th, 50th and 10th percentiles (descending convention). Alternatively one can simply refer to low, mid and high values.

Figure A1. **Probability density function and cumulative distributions**



The shape or type of the distribution should be chosen such that it best reflects the structure and behaviour of the variable. For example, costs are often skewed to the right because costs in reality are more likely to turn out to be higher than the original estimate, rather than lower. As ranges of input variables (costs, sales volumes, timing estimates) are often based on or influenced by judgements, it most of the time suffices to rely on stylised distributions. A combination of uniform, normal and log-normal distributions usually suffices. It is more important to carefully consider the ranges to be used.

Another type of uncertainty is a question that can only be answered yes or no. A typical example in oil exploration is whether a well to be drilled will find hydrocarbons or not. Such uncertainties can be depicted by a Bernoulli distribution. There can also be a question with more than two possible answers, e.g. several hypotheses or cases for some future development. Each case can be given a weight; the weights need to add up to 1.

2.3. Uncertainty assessment

The crucial step in a probabilistic analysis is the uncertainty assessment. Typically, two inputs are needed: historical data analysis (to the extent available) and expert judgement. For some parameters it will be possible to use data from previous projects, such as comparisons of estimated and actual costs. To a greater or lesser degree, an element of judgement is needed, as the project at hand may have specific

circumstances. If there are no meaningful historical data, an uncertainty range may still be characterised by low, mid and high values through the so-called expert interview approach, a structured process by which one or more domain experts are guided to arrive at a best estimate of the bounds within which the variable might range. For assessing chance factors and scenario weights, similarly rigorous procedures have been designed to arrive at well-considered probabilities.

If probabilities cannot be established in a credible way, it will be necessary to forgo the probabilistic analysis and revert to a "sensitivity analysis only" approach. Another critical success factor for uncertainty assessment, and for credible valuation analysis in general, for that matter, is the regular execution of look-backs or post-investment reviews for calibration purposes.

2.4. Translation to decision metrics

Once the uncertainties in the input variables have been established, they need to be translated into decision metrics, in most cases NPV and a capital efficiency indicator. There are various ways in which this can be accomplished, ranging from a simple weighted average of two or more scenario NPVs to more complex combinations of decision trees and Monte Carlo simulations. The latter may involve embedding Monte Carlo functions in the valuation model, but such processes can also be applied to derived approximated relationships between target decision metrics and input uncertainties.

The most efficient method is an analytical approach that uses mathematical concepts from probability theory to aggregate uncertainties. For most investment evaluations, it is possible to generate the uncertainty ranges in the decision metrics from the inputs. The output will consist of probability distributions of the NPV and, if desired, other decision metrics. From these, the P90 (lower value with 90% chance of being exceeded) and P10 (upper value with 10% chance of being exceeded) of the metrics can be inferred. It is also possible to assess the chance that the NPV will be greater than zero or establish probability thresholds for other metrics.

3. Risk management integration

In business decision processes, risk management is an established discipline that aims to identify, assess and prioritise risks, followed by coordinated and economical application of resources to minimise, monitor and control the probability and/or impact of unfortunate events or to maximise the realisation of opportunities. Although this is a valuable activity in itself, it becomes more powerful if it is closely linked to the probabilistic valuation described above.

Identification of risks is an on-going process, as new risks may pop up or new insights develop. Yet it is important to organise specific efforts to explore the context of an investment opportunity and identify risks. This may be done through workshops, brainstorming, expert interviews, the use of checklists, database references (if available) and the like. Such an identification exercise usually yields a long list of a great variety of risks. To develop an overview it is then required to organise the risks in a breakdown structure. The risk register is a repository of all risks and is the basis for the risk management activities. It should be maintained on a regular basis.

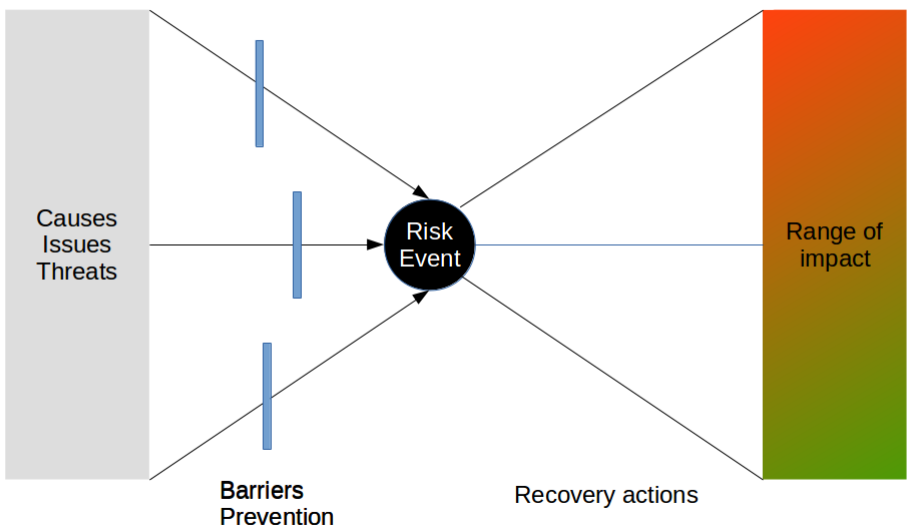
A risk will have one or more causes: issues, threats, conditions. These could lead to a risk event, although preventive actions may be taken and barriers put in place. If the risk event nevertheless does happen, it may have various types of impact, some bad, but perhaps some good, which will be attenuated or steered by recovery actions. A good way to think about a risk is by applying the bow tie concept (Figure A2).

The bow tie concepts guides thinking in the following way:

- What are the causes?
- What would the risk event be?
- What would its impact be?
- What barriers, prevention or mitigation steps, and recovery actions could be taken?

Once a risk has been articulated and categorised, it needs to be evaluated and its possible impact considered, along with the likelihood of occurrence. This could follow from group discussions or interviews and should be done for every risk in the risk register. As the register will often contain many risks, this initial assessment can only be coarse, e.g. distinguishing between high, medium and low likelihood or impact. The risk assessment matrix is a visualisation of all or some of the risks in the risk register, with impact plotted on the horizontal axis and probability on the vertical axis. The purpose of such a diagram is to communicate the risk severity; it can serve as the basis for discussions.

Figure A2. **The bow tie concept**



Once a good sense of the most important risks associated with the investment project has been arrived at, the next step aims to quantify them. Although the objective of risk management is to put in place risk mitigation, it will be found that for many risks no or only limited mitigation may be possible. Such risks just need to be accepted. However, it is then quite appropriate to ensure that these are incorporated in the probabilistic valuation so as to provide a holistic perspective to the decision makers. This is only possible if such risks can be credibly quantified.

The first step is to consider the risk model for each risk to be quantified. The risk model will shape the discussion and quantification structure. Of course, the simplest model that leads to meaningful discussion and quantification should be chosen. A few possible examples, among several:

- Only a range, a continuous probability distribution (e.g. schedule uncertainty range for some activity)
- A risk event with a certain quantifiable impact (e.g. a possible intervention by a third party that leads to a specified delay)

- A risk event with multiple outcomes (e.g. a new regulation that will be put in place, with several possible versions to choose from).

The elements of the risk model will then be quantified. For a potential risk, the probability needs to be assessed using a structured, evidence-based process. There are also structured ways to assess ranges of variables (e.g. the time something will take, a cost). An analysis of competing hypotheses may assist in assessing a risk event with multiple possible outcomes. These assessments are best conducted in workshops, as debate and challenge are indispensable for mitigation of contributors' potential biases.

The quantification thus obtained can be fed into the probabilistic analysis as described in Section 2. It is likely that not all risks in the risk register can or should be treated in this way. Only risks with significant impact should be quantified. The risk model should be appropriate and there must be enough evidence to underpin probability and range assessments. Sometimes, risks are too intangible to allow for a credible quantification. This can be the case particularly for risks associated with the broader business environment when making long-term decisions: political issues, economic outlooks, regulatory matters. In such cases it may be advisable to use a different approach: scenario thinking.

4. The use of scenario thinking

4.1. The scenario concept

The term "scenario" here means an alternative possible future of the business environment. A set of scenarios is used to explore significant contextual uncertainties that are relevant for an organisation. Generally, the organisation for which a set of scenarios is developed does not feature in such an alternative future as an actor; i.e. it cannot influence a scenario. However, in some contexts this is not inconceivable. For example, the United States will be an actor in a set of global scenarios, but a small country will not. An individual company will be an actor in scenarios if the contextual environment is restricted to specific driving forces and uncertainties with which the organisation has some interaction. However, the more common understanding is that scenarios are used to describe potential developments in a contextual environment where the organisation's influence is limited.

Scenarios are not forecasts. They are a set of possible outcomes, including a narrative of how and why such outcomes would occur. They are prepared in recognition of the fact that many contextual uncertainties often make forecasting a futile exercise (although this does not mean forecasting can be done away with altogether). Scenarios are a way to better understand the uncertainties that can invalidate forecasts. But they will not eliminate uncertainty.

The objective of using scenarios is always to assist in decision making, directly or indirectly. This can be a straightforward investment decision or a decision to choose a strategy (and the latter choice will no doubt imply future investment of some sort). If, as a result of the scenario analysis, one decides to do nothing, that is still a decision. The same applies if one decides to do even more analysis and postpone important decisions.

One way is that scenarios are an implicit means of taking on board perspectives on future uncertainties when making decisions or developing strategies. Absorbing scenarios, or (much better) being involved in devising them, allows decision makers and managers to further develop their mental image of the business environment. The impact of scenarios is pervasive rather than very pointed or focused. Scenario thinking can play a role for decision makers by supplementing their experience, intuition and general knowledge of the world, serving as "memories of the future". This category may be referred to as exploratory scenarios. They may still be built around a focal question or strategic theme, but it is less explicit and quantitative than what is aimed for with focused scenarios (see below).

Another way to incorporate scenario thinking in decision making is to steer towards a more percussive impact: scenarios that allow one to map out, analyse and sometimes quantify very specific uncertainties that are pertinent to a decision to be taken. It then becomes clear how possible outcomes of such contextual uncertainties would affect the decision criteria. The scenario method in this context is closely linked to financial and economic modelling, sensitivity calculation and probabilistic analysis. The use of a scenario approach is useful when uncertainties cannot be properly described with quantitative probability distributions. Such scenarios can be simple, looking at only one or two key contextual risks, as in the case of some tax/regulatory scenarios. Or they can also be very involved and complex, looking at a range of interlinked uncertainties that somehow ultimately would affect the attractiveness of the investment or project (Section 4.5).

Although in the long run scenarios need to serve the decision-making process, directly or indirectly, there are certainly other, more immediate, benefits that sometimes come to the fore. A scenario exercise provides a useful structure for discussion and engagement which can greatly enhance the understanding of the various issues by the participants, and also help them better appreciate each other's professional perspective. Developing scenarios is sometimes seen as a comfortable, "safe" activity. After all, the participants all know they are painting futures that will never precisely come true. This can thus be a way to keep engagement going between parties with vastly different views and interests. Another use of scenarios is to trigger or contribute to a public debate. In this context, the characteristics of scenarios make them relatively "innocent": one does not need to support a particular unpopular scenario or genuinely believe it will be the outcome. Yet it can be discussed and explored as a what-if, however unpleasant or unlikely. Provided all participants understand these principles (and that is not always a given), a scenario approach can be useful as a platform for exchange of views. An extensive discussion of the concept of scenarios can be found in Van der Heijden (2005).

4.2. Contextual uncertainties

With the scenario technique the aim generally is to analyse contextual uncertainties – that is, uncertainties in the business environment that cannot credibly be quantified and captured by either continuous or discrete probability distributions. They are not well-defined quantitative inputs for a valuation model or cost-benefit analysis. Contextual uncertainties are often phenomena that are beyond the domain of a single investment or strategy decision. They affect multiple investments, most likely in different ways. However, a contextual uncertainty can also be specific to one investment project. This section briefly reviews some key contextual uncertainties relevant for multinational companies.

The geopolitical relationships between the great powers will clearly shape the future world and substantially affect the contextual environment for business. The shift from West to East has already meant a tremendous change in the geographical spread of the centres of gravity for many markets. For example, the instability in the Middle East affects the oil price and vice versa. There are fundamental questions around the future development of Russia, particularly regarding its relationships with the EU, the US and China. Migration is becoming a major issue, not only for Europe but also for other continents. Much uncertainty exists on the future of Europe. Will it become more federalist or will a national orientation gain further ground? Depending on the type of business, the investment or the strategy direction at hand, geopolitical issues can affect important contextual uncertainties for decisions to be made.

Linked to geopolitics is the aspect of macroeconomics; the health of the global economy is a key factor. Although there is a predetermined element, largely linked to population growth, there are also major uncertainties and risks. These include the potential for new crises as well as uncertainty regarding the further development of various national economies. The BRICs (Brazil, Russia, India and China)

initially recovered well from the financial crisis of 2008-09 but have most recently seen a slowdown and an important question is whether this is temporary or a long-lasting trend. When looking at an investment opportunity or strategy in a particular country, the specifics of the national economy may be more relevant than global aspects (although there are always links). Even for investments in, for example, health care this may play a role, as the available national budget will partly depend on the state of the economy.

Of course, in the end people shape the business environment. Therefore the ways in which various dimensions of the social fabric evolve may be key factors that need to be considered as contextual uncertainties. Some trends, such as demographics, are reasonably predetermined. Others may be more uncertain: e.g. consumer preferences, spending patterns, migration trends, community attitudes towards neighbouring industrial projects, education, health care requirements, and responses to liberalisation and globalisation.

Even in a laissez-faire economy, a considerable part of the business environment is shaped by regulation. Important manifestations of regulation are the tax, labour and environmental laws. There can be very specific areas of regulation that are vital to a certain industry. For example, in recent years, regulation in the financial sector has attracted considerable attention and debate. For energy companies it is crucial to have a view as to the future of carbon pricing. The appetite of pharmaceutical companies for investment in research on new types of antibiotics is mainly driven by regulation. There will be uncertainty as to whether there will be more or less regulation and who will primarily shape it (for example, the EU or individual European states) and how it will evolve.

There are many examples that demonstrate how difficult it is to accurately predict technological change. For example, Albert Einstein declared in 1932 that there was “not the slightest indication that [atomic energy] will ever be obtainable”. There are many cases however where certain technological developments were foreseen. For example, when GPS was still in its infancy in the 1980s, there was a clear vision that at some point in the future accurate positioning devices would be incorporated into watches. The fracking technique used in the production of oil and gas had been known for many years before it was widely implemented by the oil industry For many businesses, technology, if only indirectly, represents a contextual uncertainty that will be worth exploring in terms of pace and direction of development, as well as the potential players and possible implications.

There can also be contextual uncertainties at the national or local level, such as coming elections or longer-term trends in distribution of political power and in regulatory matters. The national economy will often be an important theme, along with, more specifically, possible developments in exchange rates, inflation and interest rates. Various issues may be at play in the direct vicinity of the investment project may need to be treated as contextual uncertainties. If certain specific identified risks exist, it will be preferable to quantify them. However, this may not always be possible. Examples are the general behaviour of a joint venture partner or of particular stakeholder groups.

4.3. Exploratory scenarios

As with many developments, the origins of scenario planning go back to the US military after the Second World War. Herman Kahn is considered the father of scenario planning through work he did at the RAND Corporation particularly in the early 1960s (RAND Corporation, 1948-60).

Shell is a company well known for its scenarios (Wilkinson and Kuper, 2014). In 2012, it celebrated of 40 years of Shell Scenarios. Pierre Wack, a key figure in the early days, led the scenario team in the early 1970s. A famous episode concerns the 1973 scenarios, which included the possibility of higher oil prices and an energy crisis. When the oil crisis hit in October 1973, Shell was better prepared than its

competitors. Another significant period was before the fall of the Iron Curtain, when Peter Schwartz, author of The Art of the Long View (Schwartz, 1991), was head of the scenario team. The disintegration of the Soviet Union had indeed featured in the Shell Scenarios of the 1980s. In the 1990s, globalisation and liberalisation were key themes. For example, the 1992 Shell scenarios (with a time horizon up to 2020) already discussed the possibility of the rise populist parties as a reaction to globalisation. In the first decade of this century, considerable focus was put on the topic of climate change. The latest Shell Scenarios, Mountains and Oceans, were published in 2013 (Shell, 2013). It is worth noting that at Shell the primary impact of the scenarios has been through senior management developing a better understanding of the future business environment, rather than the focused scenario approach also discussed in this paper.

In Singapore, scenario planning has been an important component of governance since 1991. In 1995, a formal Scenario Planning Office was set up. As a small country Singapore has no influence on the global events to which its successful economy has huge exposure. Hence it is particularly important for Singapore to be prepared for a range of possible global and regional developments.

The concept of scenario thinking (or scenario planning) has thus been around for decades. Apart from the above examples, many companies and governments have attempted to use scenarios for strategising and other purposes.

Whether there is a specific focal question or just a desire to explore the future of a business, sector, country or municipality, the broader scope of the exploratory scenarios to be developed needs to be bounded by:

- a set of themes (and perhaps an indication of depth per theme)
- a geographic area
- a time horizon.

By theme this paper means a sector, business or a phenomenon. The themes to be chosen need to be relevant. A company in, for example, the steel business would explore coal mining, the transport industry, macroeconomics, geopolitics, materials technology, etc., but perhaps not education, liberal arts, nanotechnology and agriculture. Nevertheless, sometimes one may want to include elements of non-adjacent themes to provide further background to the scenarios without treating them in depth.

Within a theme one or more key contextual uncertainties (discussed in Section 4.2.) may be identified. They are analysed and the possible outcomes grouped logically following one of the methods discussed in the following section, resulting in a set of usually two to four scenarios.

Even though exploratory scenarios have a strong qualitative element in the way they are presented (by means of narratives), this does not mean quantification cannot be an important or even central element. Scenarios describe trends. It may be necessary to express these trends quantitatively in order to provide more meaning and significance. If a trend is, for example, that a population will be ageing, it will be useful to indicate at what rate and over what period. This may imply the need to do research and modelling. Other trends that are candidates for quantification are economic growth, supply and demand developments, employment levels, etc.

Whether it is worthwhile to go through the effort of providing a quantitative underpinning will depend considerably on the purpose of the scenarios and the significance of certain trends within them. When scenarios are to be used for effective decision making (focused scenarios), quantification is usually a requirement.

For exploratory scenarios it will generally not be expected or desirable to assign probabilities, as their nature and purpose do not warrant doing so. Exploratory scenarios involve a diverging thinking mode in which a discussion about probabilities can be counterproductive, causing thinking to concentrate on the "most likely" scenario and obstructing a free flow of exchanges and ideas around more remote alternative futures. At the same time, scenarios' plausibility must be ascertained. Wild and unproductive fantasies are to be avoided. There is a delicate balance to be achieved here.

4.4. General scenario building

The core process of the scenario technique is the elicitation of insights from experts. There are certainly topics that are studied within the context of exploratory scenarios by means of modelling and quantification. However, the piecing together of the overall concept is based on logic as well as insights from and discussions with relevant experts. There are two main approaches to engage with domain experts: through interviews and through workshops. Both should be used.

The advantage of interviews is that time is created to record the insights and knowledge of a single domain expert, or perhaps two, allowing for focus and depth. There is limited scope for discussion and challenge, except to the extent that the interviewer can probe and act as a discussion partner. For that to be successful, adequate preparation and desktop study beforehand are important.

Workshops are attractive in that various experts and stakeholders can intensively engage on topics and arrive at insights and conclusions they would likely not reach on their own or in more isolated engagements. Workshops are usually composed of plenary presentations, group discussion and breakout sessions. The last can be a very valuable element as they allow more focused discussion than a plenary session if the workshop group is large. Breakout sessions also ensure that all participants get time to speak. Different techniques for facilitating workshops include working with flipcharts, hexagon mapping, and brainstorming. Scenario building, however, should not rely only on workshops which are just one important element in the process, along with interviews, desktop studies and quantitative modelling.

Any scenario project should start with a framing exercise to establish purpose and scope. Framing is best done through a workshop, but may also be achieved through a set of interviews and/or discussions.

Developing the scenario scope may entail:

- articulating the objective and focal question(s)
- choosing the geographical area and time frame
- brainstorming issues, uncertainties and possible events that are directly or indirectly relevant for the business or activity
- shaping the transactional and contextual environments by e.g. determining which uncertainties and driving forces are more remote and which are more imminent
- grouping the driving forces and uncertainties in themes.

There are multiple approaches for taking the results of framing further into a set of exploratory scenarios. A few of these are discussed below.

Deductive and inductive approach

The deductive method aims to develop an overall structure in the data and considerations before constructing the scenarios. There are two main frameworks: an event-driven structure and one built around a few critical uncertainties. The event-driven approach aims to identify several events as branching points towards possible alternative futures. The best-known approach to scenario development is based on the selection of two or three critical uncertainties. This is done by further developing a list of uncertainties/driving forces and plotting them against two axes: degree of uncertainty, and impact on the business or relevance to the focal question articulated.

For each critical uncertainty selected, two potential outcomes are identified. Two critical uncertainties, for example, thus yield four combinations. Other uncertainties are then folded into the structure of these four skeleton scenarios in some logical way. These quadrants form the basis of four scenarios to be developed.

Induction, on the other hand, is a process of reasoning by which a general conclusion is drawn from experience or experimental evidence. Below is an example of steps which can be taken to build scenarios using an inductive approach:

- Identify events that could happen in the future within the themes.
- Identify predetermined trends.
- Identify uncertainties (trends or event outcomes) and, for each uncertainty, multiple scoping outcomes (and hence multiple data points per uncertainty).
- Cluster the data points that seem to logically belong together and order them chronologically.
- Take each cluster and develop it into a consistent storyline.

The challenge of the inductive approach is that it is iterative, which implies that the process often needs multiple rounds improving the scenarios before a satisfactory result is achieved. Incremental approach

The incremental approach takes an existing forecast or static base scenario as a starting point. This approach can be used in situations where scenario development is not an established practice and a lot of effort may have already gone into the development of a forecast (or the “official” future).

The steps to take include:

- assessing which major issues and threats can be identified in relation to the official future
- assessing which are the most important (other) uncertain variables
- building one scenario per major issue, choosing possible outcomes that can logically be strung together as deviations from the official future.

In the process, both trends and specific actors may shape the respective scenarios. The number of major issues should be restricted to no more than three, to avoid ending up with too many scenarios. This approach resembles sensitivity analysis, but is different as a sensitivity analysis only scrutinises the impact of different outcomes of a single variable, while scenarios always look at logical causal relationships across multiple variables or uncertainties.

Storytelling

Finally, irrespective of the approach used it is useful to present scenarios as provocative and memorable stories. Ideally, these would link current events and circumstances to possible future developments. The stories will describe trends ("economic growth is strong", "the population gradually shrinks") but may also contain events ("the euro zone breaks up", "Tata acquires Procter & Gamble"). Such events would be included to illustrate the trends that constitute the scenarios, or to signify certain branching points, though it is usually better to limit the number of discrete events in scenarios to the absolute minimum, as too many may undermine their credibility. Anchoring scenarios in a persuasive narrative also helps verify their internal consistency.

4.5. Focused scenarios

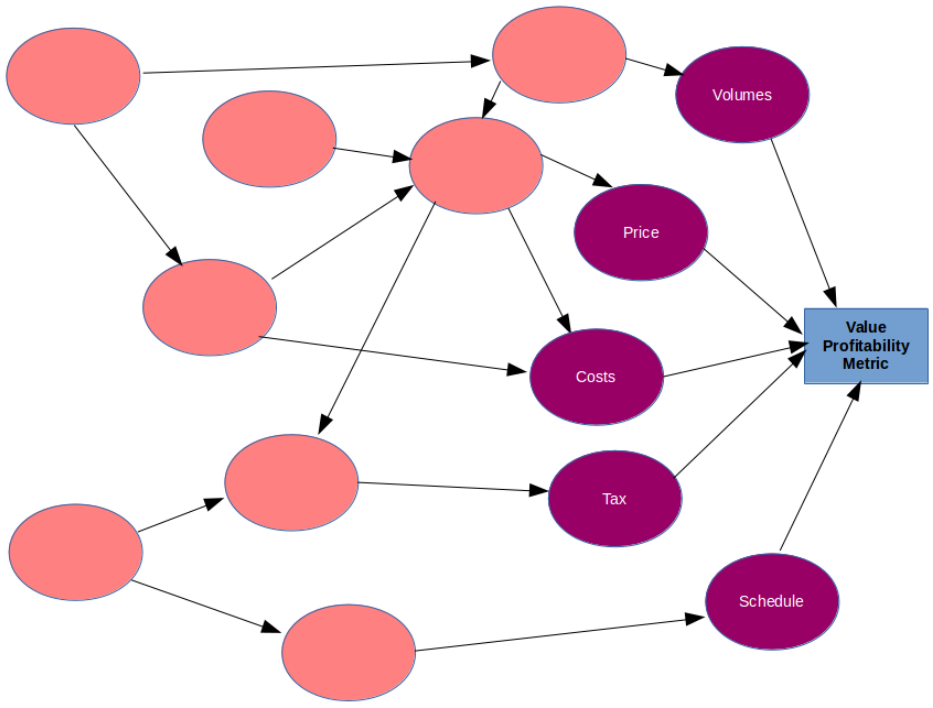
One particular challenge of setting out high-level scenarios is how well they can support decisions on investments or strategies. This issue can be addressed by developing a set of more focussed scenarios.

The influence diagram

One way to focus the development of a set of scenarios on specific decision criteria is by means of an influence diagram (Figure A3). If the purpose of the scenarios is to explore uncertainties that are relevant for investments or business strategies, then clearly economic or financial indicators will be important decision metrics. These could be NPV, internal rate of return or discounted return on investment, but usually some combination. One then identifies the quantities that directly determine this metric, including revenues (driven by volumes and prices), costs, taxes and schedule. From these quantities one works backwards and identifies the driving forces that in turn influence the primary inputs (volume, price, cost, tax and schedule). The system can be expanded as deemed required and meaningful. A schematic influence diagram is depicted in Figure A3.

The purpose of the influence diagram is to ensure that the scenario development retains its focus on the decision to be taken or strategy to be pursued. By working backwards from the decision criteria, it is ascertained that all relevant factors are covered. The scenarios are not expanded wider than necessary and the relevance for the decision-making processes is immediately clear. An influence diagram provides a graphic depiction of the key relevant factors and uncertainties, their interrelationships and their links to the decision criteria. It is thus a structuring and communication tool. From here on, it will be necessary to use one or more of the scenario development techniques discussed in Section 4.4. The core subsequent steps are to establish the possible range of outcomes of the various uncertainties, and group them in a logical way.

Figure A3. **A schematic influence diagram**



Links to exploratory scenarios

Independent, one-off focused scenarios can be built, but the concept becomes more powerful if they can be linked to exploratory ("umbrella") scenarios. A company, institute or government might have available a set of exploratory scenarios that constitute alternative futures covering a relevant geographical area (whether the planet or just a city), some relevant themes and the required time horizon. It is even conceivable that suitable scenarios are available in the public domain. Next, a review is conducted of the driving forces and uncertainties represented by the ovals in the influence diagram. Which of these already have some coverage in the exploratory scenarios? What do the exploratory scenarios say about them? What logical correlations are made in the exploratory scenarios? How would that translate to the focused scenarios? It will likely be found that a number of uncertainties relevant to the decision to be made are not covered in the exploratory scenarios. For those uncertainties a dedicated effort is needed to come up with possible outcomes. Thought must be given to how these outcomes could logically link to the elements already described in the exploratory scenarios. In this way, the exploratory scenarios serve as a thinking template.

Another exercise of value is to start at the other end: review the exploratory scenarios and consider whether all factors and considerations explored in them would have some bearing on the investment decision or strategy which is the subject of the focused scenarios. Have all dimensions been covered? Are there uncertainties or driving forces that need to be added to the influence diagram of the focused scenarios?

In summary, the following workflow is suggested:

- Work from the decision criteria and explore driving forces and uncertainties using an influence diagram.
- Consider links with the umbrella exploratory scenarios (if any are available).
- Use the exploratory scenarios to review whether the influence diagram is complete.

This will ensure that the process and evaluation consistency across multiple investment decisions and strategies, as well as the relevance of the scenario work for the decisions at hand.

The overall concept would be dynamic and iterative, with different "flavours". Some decisions may have little to do with topics covered in the exploratory scenarios. Other focused scenario exercises may lead to changes or updates of the exploratory scenarios.

The next step is to provide further detail around the possible outcomes, develop brief narratives and group the outcomes to create the scenarios. The narratives should follow the principles of storytelling discussed in Section 4.4., but they should be kept brief and fit for purpose.

For the overview it is be best to arrange the narratives in a table (one table for each scenario). The headings in the table might be: topic/uncertainty/driver, description, possible outcomes, impact. The impact column should mention which other drivers/uncertainties are affected and how. Several approaches can be thought of to capture this information efficiently.

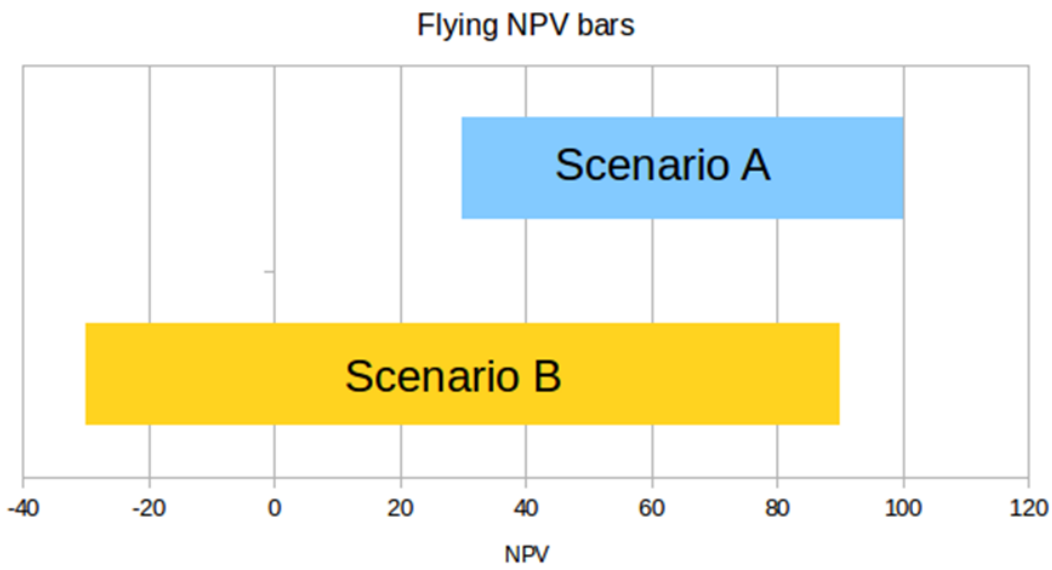
Once one has a set of scenarios that adequately describe possible options concerning the future business environment for the investment opportunity at hand, it is necessary to assess what the implications may be for the decision metrics. In the end, decision makers will primarily look at the value and capital efficiency of an investment, even though other criteria can also be important. However, where other issues cannot be translated into monetary impact, they will need to be treated separately and expert judgment needs to be used.

The influence diagram depicted in Figure A3 sheds light on how a value profitability metric of a focused scenarios could directly or indirectly be affected by volume, price, schedule, costs and tax. This analysis could be supported by the use of econometrics or system dynamics which uses differential equations to determine time-dependent interrelationships between different variables.

Many quantifications underpinning investment decisions and strategy development, however, have a considerable level of uncertainty, especially if estimates relate to the longer term. Hence, accurate modelling of *all* contextual uncertainties and their interrelationships is usually not required or it is in fact impossible. Hence, it is often useful to selectively analyse key factors that drive costs or revenues using econometric modelling and (less frequently) system dynamics. For other factors it may be necessary to resort to expert judgement. For the process to work, analysis, logic and pragmatism need to go hand in hand.

Once future trends (where relevant) have been identified, quantified and correlated, the impact on one or more of the primary drivers of scenarios can be estimated. For example, certain economic scenarios can translate to a specific range for exchange rates or commodity prices. A particular political direction may have a bearing on tax assumptions, or on schedule implications for permits and regulatory issues. Such estimates can be processed through an economic (or cost-benefit) model to arrive at ranges for the decision metrics. If such analysis is conducted probabilistically, as discussed in Section 2, it is possible to derive a range for the key decision metrics per scenario. This may be depicted by means of (in this case) so-called flying NPV bars. Figure A4 shows an example of NPV ranges for a hypothetical opportunity under two different scenarios.

Figure A4. **Example of flying NPV bars**



The advantage of this semi-quantitative approach is that the implications of the scenarios become meaningful and relevant for the decision at hand. This is only of value if the decision makers, when presented with such analysis results, fully grasp the background, caveats and limitations.

5. Integration and decision making

Decision making usually involves continuous dialogue between the project team and the decision maker or decision board. Decision makers are advised to monitor the process through the decision quality lens and continuously test whether the six principles to ensure a quality decision making framework are followed (see Box A1).

Often there are multiple objectives and decision criteria. The decision maker then needs to make trade-offs. It is very helpful if this is done explicitly, with the decision criteria defined up front. These will often be economic metrics but there will also be dimensions that are more difficult to express in monetary terms, such as safety, environment, public relations, social acceptance, contribution to communities and local employment. There are various approaches to handling multiple-criteria decision processes (e.g. Hammond et al., 2002). A simple scheme can consist of scoring and using relative weights across the set of criteria. Other methods are concerned with successive elimination of options.

Economic or cost-benefit analysis, probabilistic analysis, risk management and risk quantification as well as scenario thinking should be integrated and properly woven into a value proposition that provides maximum clarity to decision makers. The objective is to illuminate as well as possible the various types of risks and uncertainties associated with a particular investment opportunity and its benefits. But this will never take away the need for decision makers to exert their judgement, using their experience and intuition.

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Notes

[1] New Zealand's Ministry of Transport has recently produced several papers discussing this trade-off, for more information see: http://www.transport.govt.nz/news/multi/regulation-2025-foundation-papers-released/

[2] The latest results were not yet published at the time of writing this report.

[3] Note that estimates of the size of the impact of public investment on output vary due to uncertainties around fiscal multipliers on the demand side and inefficiencies on the supply side.

[4] See Eddington (2006) for a discussion.

[5] https://www.mof.go.jp/english/budget/budget/fy2003/brief/2003-09.htm

[6] http://www.mlit.go.jp/sogoseisaku/point/sosei_point_tk_000003.html

[7] For more details see oral statement to Parliament by the Secretary of State for Transport on 15 November 2016, https://www.gov.uk/government/speeches/secretary-for-state-for-transport-decisions-on-hs2-phase-2b-scheme

[8] See the high speed rail master plan of May 1991, implemented by Décret n° 92-355 of 1 April 1992; and the motorway master plan implemented by the same regulation.

[9] For example, over 50% for the A45 motorway project between Lyon and Saint-Etienne, almost 50% for the Tours-Bordeaux high-speed line, 100% for the CNM (Nîmes-Montpellier bypass) high-speed line.

[10] Since the beginning of the 2000s, rail freight transport has decreased by 40% in France. Since 2008, the increase in TGV high-speed train traffic has been low, +0.5% per year. The reality of this traffic has not confirmed the hopes of the Grenelle environmental law.

[11] For more information on the SNIT see http://www.developpement-durable.gouv.fr/IMG/pdf/projet_de_SNIT_181011.pdf

[12] Named because of its scale and the paradigm shift in policy it represented after the negotiations over the social compact that ended the student and worker unrest of 1968, negotiated at La Grenelle.

[13] Mobilité 21, "pour un schéma national de mobilité durable" http://www.developpement-durable.gouv.fr/Remise-du-rapport-Mobilite-21-pour.html

[14] The plan was extended for two years before integrated into Priority Plan for Social Infrastructure Development in 2003.

[15] https://www.mof.go.jp/english/budget/budget/fy2003/brief/2003-09.htm

[16] http://www.mlit.go.jp/sogoseisaku/point/sosei_point_tk_000003.html

[17] For more details see https://www.gov.uk/government/topics/government-efficiency-transparency-and-accountability and https://www.gov.uk/government/news/letter-to-government-departments-on-opening-up-data

[18] See in particular issue 6, http://www.lgv-sea-tours-bordeaux.fr/uploads/media_items/lisea-express-6-dossier-elus-acteurs-de-la-concertation.original.pdf

[19] The central scenario represented the results generated by the Airports Commission's central forecast which assumed no step changes in the airline industry in terms of airline and airport business models. The central forecast relied on central assumptions by other institutions on, for example, the future global economic growth and the price of oil.

International Transport Forum

Strategic Infrastructure Planning

International Best Practice

This report reviews experiences with strategic infrastructure planning with a view to identify international best practices. Governments play a critical role in providing the framework for investment in the transport, energy and water infrastructure on which economies depend. Long asset lives and large sunk costs make such investments particularly subject to risk and uncertainty. A long-term strategic plan that integrates specific projects reduces such risks by setting out a stable set of the priorities for future investment. This report is the product of a roundtable organised by the International Transport Forum at the OECD and the UK National Infrastructure Commission.

This report is part of the International Transport Forum's Case-Specific Policy Analysis series. These are topical studies on specific issues carried out by the ITF in agreement with local institutions.

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