Chapter 1. Summary of discussions

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Demand forecasts for the medium to long term are essential to the successful planning and delivery of major airport infrastructure but the track record of airport demand forecasting appears to be mixed. The first priority area is therefore to improve forecasts and the report puts forward four key recommendations:

- Use quantitative methods to analyse the key drivers of airport demand.

- Use expert guidance to help interpret the quantitative results.

- Quality-assure the analysis and counter the risks of optimism bias.

- Reflect the risks and uncertainties that arise in even the best forecasts.

The second priority is to make effective use of demand forecasts in airport infrastructure planning. The main purpose of recognising and quantifying risks and uncertainties in future airport demand is to help to develop useful risk management measures. Approaches divide into two broad groups:

- Risk sharing arrangements.

- Flexible strategic/dynamic strategic/adaptive planning.

Thirdly, it is important to recognize that however successfully all of the foregoing is carried out, there are likely to remain material risks and uncertainties in even the best airport demand forecasts. The challenge is thus to make the residual uncertainty apparent to decision-makers without undermining the value attached to the economic appraisal of prospective investments.

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Introduction

Expanding airport capacity in cities is both important and controversial. It is characterised by a fundamental trade-off between economic and environmental goals. Good transport infrastructure is of key importance for productivity and economic growth but airport capacity that is highly accessible to central city areas means that residents suffer more noise, air pollution and landscape degradation (in addition to the wider impacts of additional greenhouse emissions). Experience around the world shows that this trade-off is an important and contentious policy issue, and that there are no straightforward solutions (ITF, 2014)) for an overview of these issues.

Demand forecasts are an essential tool for the consideration of extra capacity. Growth in air travel signals the importance of connectivity, but also drives increasing pressure on capacity. Airport assets are often, but not always, long-lived with long lead times. Forecasts of future demand are thus a key determinant of the case for adding capacity. And forecasting tools are also needed to measure the economic benefits and costs of this extra capacity.

Research to underpin forecasts has been extensive but large uncertainties remain. Understanding fully the drivers of past growth helps, including the impacts of past regulatory reform, longer term macro-economic and demographic trends, and innovation in technologies and business models. Understanding the likely future path of these key long term drivers, following the great recession, is important. Understanding if and when the strong historic link between growth in incomes and in air travel demand might start to weaken is important in the more mature markets. Understanding the effects of future innovations in supply (including high-speed rail in short haul markets) is critical and often particularly difficult.

Forecasts are also prone to well-recognised risks of quality shortfall or of institutional biases. Quality issues may arise when forecasts fail to reflect current best practice (proportionate to the task in hand) and there is always a risk of optimism bias to forecasts. And this, in turn, can make credibility an issue with stakeholders.

These risks, together with the uncertainties of unforeseen events – the "unknown unknowns" - mean that airport demand forecasts are a difficult challenge. Understanding the past is not easy and, and as Nils Bohr famously remarked, "prediction is very difficult, especially if it's about the future".

Overview of emerging findings

Airport demand forecasts are both difficult and very important. The discussions at the Roundtable suggested a paradox:

- On the one hand, it was recognised that airport demand forecasts are often problematic – with a track record which shows some major surprises, in terms of a large divergence between forecast and out-turn.
- On the other hand, demand forecasts for the medium to long term were judged to be essential to the successful planning and delivery of major airport infrastructure.

The Roundtable papers and discussions highlighted a wide breadth of research evidence and expertise which together can help in making progress on this fundamental dilemma. Progress is required on two fronts.

The first priority area is to improve forecasts of airport demand. The track record of airport demand forecasting appears to be mixed – with illustrations of both successes and failures. Nevertheless, a recent review of airport demand forecasts in the United States concluded that econometric modelling has been an effective tool for generating medium to long term forecasts of airport activity (whilst recognizing the potential pitfalls and noting the need for more research on how well forecasts have performed in practice), ACRP (2007). The Roundtable reached similar conclusions, and discussed various steps that might help to improve airport demand forecasts.

The second priority area is to make better use of demand forecasts in airport infrastructure planning. The aim here is to recognise the risks and uncertainties that will arise in even the best airport demand forecasts. And then, secondly, to use this analysis to help develop investment strategies that aim either to control adverse risks (that is, reduce the chances of their happening) and/or reduce their negative impacts (in the event that these adverse risks do happen in practice). And so, in this way, improve the efficiency and value of airport infrastructure investment. This is the subject of the final section of the paper.

Making better forecasts of airport demand

An overarching theme of the emerging findings on demand forecasts is the value to be gained from blending together quantitative analysis - based on econometric and statistical methods - and qualitative analysis, drawing upon expert assessment.

First, it will usually be worthwhile to use econometric and statistical analysis, of the kind elaborated in the Roundtable papers, to help understand – in quantitative terms – the key drivers that have shaped demand in the past; and use this as a starting point to forecast future demand. Consideration will need to be given to the relative merits of time series analysis or choice analysis - where the former has strengths in relation to understanding the long term socio-economic drivers of demand and the latter is particularly useful where passengers' choices – between mode, airline or airport – are a strong driver of demand. Decisions on the best forecasting method to adopt should be shaped by an assessment of prospective market circumstances. But sometimes, perhaps often, a two-stage approach will provide the best solution – using time-series econometrics to develop forecasts for a broadly defined market and choice analysis to develop forecasts for specific airports within this market, especially when airports compete for overlapping markets.

Second, it will be useful to draw upon expert guidance, perhaps using formal elicitation methods (such as Delphi exercises) to make best use of this expertise. Expert guidance will be particularly helpful in the choice of forecasting methods (as discussed above) and in advising on the interpretation of the emerging results and the development of forecasts from these results – in particular, assessing how far the past is likely to provide a good guide to the future and, if not, in what ways model parameters should be amended to reflect this. And expert guidance will also be valuable in building scenarios – that is, alternative future paths of development – for those key demand drivers that cannot be predicted with any useful precision. Scenario analysis is likely to be particularly helpful in considering the future development of airline networks, and the associated implications of this for competition and service provision at different airports.

Third, it will be important to constrain the risks of optimism bias. Here expert guidance on emerging forecasts – as described above – and independent peer review will be helpful, together with transparency and engagement with the broad range of stakeholders with an interest in the forecasts, and through the benchmarking of forecasts to the existing research literature. For example, Gillen, Morrison and Stewart (2002) provide a summary of research evidence on price and income elasticity. InterVISTAS (2007) also provides an overview and suggests some comparators, as does Oum, Fu and Zhang (2009).

Finally, we need to recognise that however successfully all of the foregoing is carried out, there are likely to remain material risks and uncertainties in even the best airport demand forecasts. The key issues this raises are twofold. First, there is the question of how risks and uncertainties should best be measured, and in this way recognised, in the presentation of airport demand forecasts. That is, how we can be (appropriately) more modest in presenting forecasts. The second question is how these risks and uncertainties are best taken into consideration in the planning of airport infrastructure investment, with the aim of controlling adverse risks and/or reducing their negative impact, and in this way improving the efficiency and value of infrastructure investment. The challenge is thus to make the residual uncertainty apparent to decision-makers without undermining the value attached to the economic appraisal of prospective investments.

Making better use of demand forecasts

Consideration of how best to reflect risk and uncertainty suggests a second important paradox. On the one hand, risk and uncertainty are acknowledged to be an important characteristic of airport demand forecasts, with important consequences. On the other hand, these risks and uncertainties are often not subject to serious analytical consideration, nor are they recognised, in an effective way, in investment planning. The Roundtable papers and discussions suggest that tools are being developed to do both.

As far as analysing risks and uncertainties is concerned, there will again be advantages to an approach which blends together the quantitative and the qualitative. That is, an approach which first uses techniques such as Monte Carlo analysis to get quantitative measures of the risks and uncertainties which are "in the model", using econometric and statistical analysis of past data. But an approach which also recognises that a model that successfully fits the past may not equally fit the future, and which uses expert opinion – perhaps codified using formal elicitation techniques – to consider whether and how additional risks should be added to the model's forecasts. In some cases, there will be a sufficient research base to develop useful subjective probabilities to supplement, or substitute, those suggested by the model. In other cases where uncertainties are greater, then expert opinion can help develop plausible alternative scenarios, even if it is not possible to sensibly say which, if any, of these scenarios is most likely to happen in practice. The value of such scenarios is both to reveal the scale of uncertainty and to provide a basis for testing the robustness of a project to uncertainty.

A particularly important source of uncertainty discussed at the Roundtable, where scenario analysis is likely to be worthwhile, relates to future airline network development. Whilst the research evidence shows that levels of air service are often an important factor in shaping passengers' choices – and hence airport demand - the airline business decisions which determine service levels are less well researched and the findings are less clear cut.

In summary, most theoretical studies of airline networks suggest that it is usually beneficial – in economic and commercial terms – for a network airline to focus its operations in a particular market on a single hub, although some studies nevertheless suggest that a multi-hub network may sometimes prove more efficient – perhaps in situations where there is strong geographic segmentation between different parts of the market, together with sufficient local O-D demand. And it is also possible that at very high levels of traffic there might be various diseconomies of hub size which start to off-set the benefits of density economies.

Recent empirical research in the USA (ACRP, 2013) provides some support for these findings. In particular, the study found that airlines prefer to concentrate services in a particular region at as few airports as possible, although larger carriers will sometimes operate at more than one airport in a large metropolitan region if the demand conditions provide for this. More generally, the provision of airline services at secondary airports is usually found to be shaped by the suitability of these airports for the provision of niche services by low cost carriers. These carriers tend to focus on point to point traffic, and this means that they usually choose to serve a region through a single gateway.

Experience in Europe also supports these emerging conclusions showing, first, a number of unsuccessful attempts to establish dual or split hubs (in particular, Rome-Milan Malpensa, Heathrow-Gatwick and Madrid-Barcelona). This lack of success seems to reflect the economic advantages of a single hub; and in the case of Milan, also strong competition from a well-established and highly accessible short-haul airport at Milan Linate. However, the European experience also shows, secondly, a number of examples of legacy hubs – that is hubs inherited from the regulated era – which have been successfully sustained in a multi-hub network (for example, Paris-Amsterdam, London-Madrid or Lufhthansa's configuration, constructed around its primary hub at Frankfurt). The continuing success of these multiple hubs seems in many cases to reflect a degree of complementarity, with relatively strong geographic segmentation in their markets, typically the various partner hubs are located in different European countries with different historic patterns of trade and business connections – Burghouwt (2013), perhaps also reinforced by passengers' general preferences to continue using a familiar airport. However, in some other cases – for example Lufthansa's secondary and tertiary hubs at Munich and Dusseldorf – their role appears to be primarily about offering additional direct services to supplement those from the primary hub at Frankfurt, in part reflecting the evolution of capacity constraints there (see Burghouwt (2013) for a discussion of "overflow" hubs).

Finally, these uncertainties on the path of airline network development are likely to compound as we look into the future, as developments in technology bring further changes. In particular, the introduction of smaller, lower cost aircraft (such as the Airbus A350 or the Boeing Dreamliner) on long-haul services, coupled with rising demand levels as the world economy starts to recover from the Great Recession, are likely to bring a greater role for point to point services, quite possibly provided from non-hub airports, although these types of aircraft will also support the provision of additional thinner routes from existing hubs.

More generally, in presenting measures of risk and uncertainty it will be important to be transparent about which risks are included in the quantitative analysis (and which are not) and about the methods used to estimate these. It will also be important to be similarly clear about the use of subjective probabilities (and the provenance for these) and the evidence underpinning the scenario development used to consider the uncertainties, which cannot be included in the quantitative risk analysis.

The main purpose of recognising and quantifying (where possible) risks and uncertainties is to help to develop useful risk management measures. Thus the aim is not simply to predict how risky and uncertain a proposed investment project might be. Rather the aim is to help develop investment strategies which either help to control adverse risks (by reducing the chances of their happening) and/or which help to reduce their negative impact upon financial and economic returns (in circumstances where the risk nevertheless does happen; and, of course, vice versa for upside risks). The overall goal here is to help, in this way, to improve the overall efficiency and added value of infrastructure investment.

The emerging evidence discussed at the Roundtable suggested productive ways of achieving this, and thus making airport infrastructure investment more robust to the risks and uncertainties in future airport demand. Approaches divide into two sometimes complementary groups:

- The first involves risk sharing; the aim here is to facilitate control of an adverse risk (that is, to reduce the chances of it happening in practice) and/or to diversify some of the consequences – in particular, through vertical integration.
- The second approach involves a flexible approach to infrastructure investment – sometimes called flexible strategic planning; the aim here is to reduce the (net) costs that would arise if the adverse risk does happen in practice (and vice versa for upside risks, of course).

As the discussion in the previous section illustrates, an important risk to the demand forecasts for some airports – those which face a material degree of competition – is the possibility that key customer airlines may choose to relocate their business to a competitor airport. This carries the risk of under-utilised and under-remunerated infrastructure – and this risk may in turn weaken investment incentives. A common business solution to these sorts of problem is some form of vertical integration, with the aim of assigning particular risks to the parties best able to control the risk and/or to diversify it. See, for example, Kay (1993) for an overview. In the case of airports, the regulatory reforms of the last several decades have both prompted and facilitated widespread innovation in organisation and ownership (see

Gillen (2011) for a review). And these developing business arrangements quite often involve vertical relationships between airports and airlines. In practice, vertical relationships take a range of forms. For example, David Starkie (2012) discusses the role of long term contracts between airline(s) and airport that have been used to manage some of the demand-side risks to the development of major infrastructure at airports in a competitive market setting, by providing some control over the risks of asset stranding. Another example is provided by the various different methods which are sometimes used to, in effect, co-finance airport development (Fu, Homsobat and Oum, 2011). And a further example discussed at the Roundtable is provided by Paris where probabilistic forecasts have been employed since 2003 (Sallier 2010). Optimal points for new capacity, in terms of revenues and costs are determined. This provides the information required for informed negotiation with airlines that request increased capacity. When demand appears insufficient from the airport's point of view airlines can be asked to pay a risk premium if they want the airport to build early. This kind of risk premium can probably be hedged on financial markets.

It is important to recognise that the benefits of vertical links may run wider than just the facilitation of investment in long term infrastructure at airports in a competitive market setting. For example, vertical links may also be important to sustaining service quality in the face of unexpected adverse shocks (e.g. shocks related to weather or to security threats), where trust and co-operation between different parts of the supply chain will often be important to sustaining service quality.

Of course, it also needs to be recognised that long term vertical relationships carry the risk of anti-competitive restriction, where a vertical link might be used to raise the costs of market entry. There is therefore likely to be a balance of both benefits and costs to at least some vertical links. Competition authorities will need to be alert to this trade off, and the balance of benefits and costs will need to be assessed on a case by case basis. This will not be straightforward. However, the risks of an anti-competitive restraint will generally be greatest in circumstances where an airport has material market power; and this is also where the risks of expropriation/asset stranding are also likely to be least strong (and vice versa).Transparency of vertical links will also be important (although not necessarily straightforward to achieve).

It also needs to be recognised that vertical relationships can only improve the control of risks which are endogenous to the aviation business (for example, the risk that an airline will choose to move more of its business to an alternative airport). Vertical integration won't improve the control of exogenous risks (for example, a downturn in the economy), although it might help with the diversification of such risks.

Whilst risk sharing can thus help to control, or to diversify, the risks associated with airport demand forecasts, the aim of taking a flexible approach to infrastructure investment is to reduce the net costs of downside risks being realised in practice (or to increase the net benefit, in the case of favourable surprises).The basic idea behind this approach is to retain flexibility, either in the scale of the infrastructure – by holding open the possibility of adding to (or subtracting from) the intended capacity – and/or in the timing of the proposed investment, holding open the possibility of deferring or advancing the investment. The aim of retaining flexibility in these ways is to help respond quickly to unexpected traffic outcomes and, in this way, to achieve a better fit between the volume of capacity which is provided and that which turns out to be actually needed in practice. The approach is sometimes described in a real options framework. That is, an infrastructure project is developed in a way which holds open a series of options (essentially to do more or less) which can be taken up in response to changing circumstances (or not, if the central forecasts turn out to be realised).

Of course, flexibility of this type will usually come at a price. That is, holding open an option will usually add to costs. And it will usually, therefore, be less good value to do this in circumstances where demand is broadly in line with the central airport demand forecast. The key question is then how much value is added by a flexible solution in circumstances where there are unexpected traffic outcomes; and whether these unexpected outcomes are sufficiently likely to occur in practice, such as to make the flexible option a good investment.

The discussions at the Roundtable suggested that a flexible approach can sometimes (and perhaps often) be worthwhile. Flexible solutions include, in particular:

- measures that make provision for future development without, at this stage, making a commitment to expand
- measures that make provision for incremental development as traffic levels develop
- measures that make provision for switching facilities between different types of traffic (e.g. international and domestic), for example, through flexible gates
- measures that make provision for different types of aircraft
- measures that retain flexibility in the start and/or completion dates for a project.

Whilst there is a wide menu of flexible solutions which have been found to work in practice, in order to be successful they will usually need to be tailored to the specific market circumstances (current and prospective) of the airport under consideration. The Roundtable paper by Ian Kincaid and Nicole Geitebruegge of InterVISTAS (Kincaid and Geitebruegge 2014) notes that "there is no standalone method or tool that can offer the correct set of strategies" and suggests an approach which builds upon current practice (where ACRP (2012) offers a series of case studies) and then uses expert advice from airport stakeholders and subject experts to suggest solutions which are feasible and relevant to the particular airport under consideration.

The evaluation of whether particular flexible solutions are worthwhile can involve qualitative appraisal, based on expert judgement, and this is sometimes sufficient to provide a clear conclusion. In other cases a quantitative appraisal – which aims to measure the expected cost benefit return – will provide a more robust basis for decisions; although of course to do this requires some reasonable estimates of the probabilities of different scenarios for traffic growth (for example, using results from the kinds of Monte Carlo analysis described earlier; more details are provided in the Roundtable paper by Kincaid and Geitebruegge).

Several case studies of the practical implementation of flexible infrastructure solutions in North America are documented in the ACRP report mentioned earlier (see ACRP (2012), whilst Burghouwt (2007) provides a detailed case study of flexible investment planning at Amsterdam airport. Although many of the examples of flexible infrastructure work at a relatively micro level – expansion of (a part of) an individual terminal, for example – the principles of flexible strategic planning can equally be usefully applied on a larger scale. For example, de Neufville (1995) considers a choice between the development of Amsterdam airport versus the possibility of a new offshore airport; he judges this latter possibility to be an unwise commitment in a flexible planning framework. More generally still, the UK Airports Commission are following an approach that might be characterised as an application of flexible strategic planning at the level of the whole London airports market.

Drawing all this together, elements of a good projection exercise with the right blend of quantitative analysis and qualitative expert assessment are as follows.

- **Use quantitative methods to analyse the key drivers of airport demand.**

  Econometric and statistical analysis can help in understanding the key drivers of past growth trends and, in this way, help to build forecasts of how the level of airport demand might develop in the future.

- **Use expert guidance to help interpret the quantitative results.**

  Expert assessment – perhaps formalised through techniques such as Delphi – can help to understand where and why the models' analysis of the past might not fit the future and, in this way, to suggest appropriate modifications to the models' forecasting results.

- **Reflect the risks and uncertainties that arise in even the best forecasts.**

  Recognising risks and uncertainties can help to develop better investment strategies which aim to control adverse risks, and/or to reduce their negative impact, and in this way can help to improve the overall efficiency and added value of infrastructure investment. Reflecting risks and uncertainties in the forecasts can involve:

  - Using analytical methods (such as Monte Carlo) to measure risks which can be quantified (that is, risks which are "in the model" such as uncertainties on demand elasticity).
  - Using scenario analysis to explore and exemplify the impact of risks which can be recognised, but whose likelihood cannot be realistically estimated (for example, the shape of future airline network development).
  - Using event analysis to illustrate the possible impact of "unknown-unknowns".

- **Quality-assure the analysis and counter the risks of optimism bias.**

  Quality assurance can help to improve the accuracy of forecasts and, equally important, assure stakeholders that the forecasts are unbiased. Quality assurance can involve:

  - expert peer review of methods, results and forecasts – using collaborative "critical friends"
  - benchmarking of results against the research literature
  - transparency through the publication of methods and results, and engagement with stakeholders through discussion forums.

- **Deploy resource efforts proportional to the task in hand.**

  For large, irreversible, risky investments it is worth investing in the highest quality of forecasting analysis which is available, and getting the best possible understanding of risks and uncertainties. At the other end of the scale – for smaller, reversible, less risky investments – then less investment in analysis is likely to be worthwhile and in some cases market testing ("suck it and see") may be the best way forward.

Improving forecasts of airport demand

The basic problem identified with airport demand forecasts in the Roundtable discussions is a track record which sometimes shows major surprises – in terms of a big divergence between forecast and out-turn. The Roundtable papers provide some illustrations of this (Figure 2.1 from the Roundtable paper by Ian Kincaid and Nicole Geitebruegge), although, of course, some forecasts have proved to be more successful (ACRP (2012) for a range of case studies).

Hyderabad's new airport provides a further example. Forecasts before the airport was built proved completely wrong. Domestic deregulation caused an unforeseen explosion of traffic whilst international traffic didn't grow as expected because of bilateral constraints, and whilst the airport was intended to become a hub, no hub developed as no locally based airline emerged to operate one. It must always be remembered that hubs are built by airlines not airports. As Brian Pearce noted in his presentation to the meeting "forecasts fail - just when you need them".

As discussed in the introduction, all of this matters because investment in airport infrastructure is often lumpy and irreversible (with long lead times) and is often politically controversial. This in turn means that forecasts which provide a poor prediction of out-turn carry the risk of potentially costly mistakes in infrastructure planning, in terms either of the scale and/or the timing of investment. Furthermore, a poor forecasting track record will often act to weaken support for investments which are politically contentious, because the underlying demand forecasts appear open to reasonable disagreement. For both these reasons (identifying infrastructure investments that are worthwhile and then sustaining political and public support for such investment) it is important to develop forecasts that command both confidence and support (as well as recognizing the risks and uncertainties which will arise in even the best forecasts and developing investment strategies which aim to control adverse risks and reduce their negative impact).

Two further points are worth noting by way of introduction. The first is that whilst the track record of airport demand forecasting appears to be mixed – with some illustrations of both successes and failures as noted above – in practice there is very limited rigorous analytical evidence with which to form a judgement on the overall success of airport demand forecasting and the relative merits of different approaches. A recent report on airport demand forecasts in the USA identified this gap in our knowledge as a priority for future research (ACRP (2007) and the Roundtable discussions reached some similar conclusions.

Secondly, it is worth emphasizing that in the context of infrastructure development – which was the frame of reference for the Roundtable – then what is of most relevance are demand forecasts for the medium to long term. Short term shocks are of course immensely important for shaping near term operating decisions and for near term profitability. Equally they are also often very difficult to forecast, for example, the particular impact upon air services of volcanic activity. But unless short term shocks impact (materially) upon longer term demand, then the implications for infrastructure development are less significant. What matters in this context is the robustness of longer term forecasts of airport demand, which in the context of infrastructure development will need to encompass various airport activities including, in particular, passenger numbers and aircraft movements together with an analysis of prospective peaking patterns.

The Roundtable discussions showed that there is a wealth of high quality research evidence – and high quality expertise – upon which to draw in preparing medium/long term forecasts of airport demand. The discussion at the Roundtable suggested that making the best use of this expertise needed to involve both:

- choosing the right forecasting approaches ,and
- getting the best out of the models used.

We will consider each of these in turn.

Choosing the forecasting approach

A number of forecasting approaches exist, embracing both qualitative and quantitative methods (ACRP, 2007 and IATA, 2008). A degree of modesty is advisable with any approach and the object of modelling should be to illustrate and make evident the important factors and the major risks involved in shaping demand rather than to pretend that it is possible to produce an accurate picture of any specific moment in the future. Models take a variety of forms ranging from Delphi surveys to discrete choice modelling. This section briefly outlines the most important models which are used in practice.

To start with, the Delphi study technique is a structured communication exercise aimed at producing detailed critical examination and discussion of issues. Developed in the 1950s and 1960s by the Rand Corporation, the technique was designed to elicit the opinions of experts in a particular field in a systematic way. It has been described as a "succession of iterative brainstorming rounds" and is suited to forecasting complex problems and it is a tool for gaining input from recognised sources of expertise. The Air Transport Research Society uses the Delphi study techniques at their annual conferences (Mason and Alamdari (2007). IATA has used similar methods although lately it relies more on 'average opinions' and consensus building than on Delphi studies, which according to the official definition of the technique requires, among other things, anonymous contributions from the experts (Mason and Alamdari (2007). More generally, Figure 2.4 from the Roundtable paper by Ian Kincaid and Nicole Geitebruegge provides an overview of the pros and cons of the main methods for eliciting and summarizing expert opinion.

Qualitative approaches thus provide a systematic route to tapping expert knowledge in ways that can yield valuable insights. And we will go on to argue below that this should be an essential part of airport demand forecasts. Nevertheless, qualitative approaches are subject to well-known weaknesses – in particular, the risks that the experts are over- confident in their assessments, and that there are halo effects (a tendency, for example, to favour particular businesses or individuals) and confirmation biases (interpreting new information as supporting prior beliefs). All of this suggests that whilst qualitative approaches are valuable, they may best be used in addition to (rather than instead of) more quantitative approaches.

On these latter, a recent survey of airport demand forecasts in the United States (ACRP, 2007) identifies three broad categories of quantitative forecasting methods:

- market-share forecasting
- time series modelling
- econometric modelling.

The first of these – market-share forecasting – is quite extensively used, but is relatively unsophisticated. In essence, this method assumes that demand at the particular airport under consideration will in the future take some pre-specified share of total air traffic in some broader market (for example, the relevant country or region). Using forecasts for air traffic in the broader market and assumptions on the relevant airport's market share of this (usually the present share, perhaps modified by judgmental adjustment to reflect anticipated market developments) yields a forecast for future air traffic at the airport under consideration. This method would be expected to break down if the relevant airport's market share changes in the future in an unexpected way. For this reason, the ACRP report (ACRP, 2007) does not recommend this approach to forecasting, whilst recognizing that it is often used in circumstances where there is inadequate data or where resources are not available to develop more sophisticated forecasts.

The second approach – time series modelling – essentially extrapolates past trends forwards into the future, without using independent explanatory variables. In other words, this approach doesn't include economic variables that attempt to explain how key drivers might have shaped past growth in airport demand; nor, in consequence, how they might shape future demand. For this reason, this approach is of limited value in assessing the impact upon demand of alternative infrastructure projects (or other policies) or of different scenarios for developments in the economy, consumer preferences or technologies. The ACRP report concludes, however, that time series analysis can be a useful approach for short term forecasts, particularly where there are complex time relationships relating to seasonality and trend.

The third approach – econometric modelling – is the most analytically sophisticated (and also the most demanding of data) and the ACRP report concluded that it was an effective tool for generating forecasts of airport activity. The Roundtable discussion reached a similar conclusion. The ACRP report notes a distinction between two different approaches to this type of analysis:

- An approach which uses time series econometrics to help understand the key drivers which have shaped past trends in demand and which then uses this analysis as a basis for forecasting the likely path of future demand. See ACRP (2007) for an overview of this approach and Airports Commission (2013) for an example of its application.
- An approach which is based on the observed choices made by individual travellers (or groups), as between different possible destinations, modes, routes and airports and which uses this analysis as a basis for forecasting the likely development of future choices (see the Roundtable paper by Benedikt Mandel for an overview; a recent ACRP report (ACRP (2013) also provides an overview and a survey of research literature.

The time series econometrics approach is well established in airport demand forecasting. This analysis can often provide a good understanding of the factors driving past trends (ACRP (2007) for a discussion). Nevertheless, it has sometimes proved difficult to confidently unpack the separate contributions of different drivers. For example, the discussion in Oum, Fu and Zhang (2009) suggests that the positive impacts upon demand of the regulatory reforms of the last several decades have sometimes been misattributed (at least partially) to the underlying trend growth in incomes and trade; the consequence is a risk of undue optimism about the impact which future growth in incomes and trade might have upon airport demand; in other words, an overestimate of the income elasticity. Combining time series and cross-sectional data (in a panel), where feasible, may help here (InterVISTAS (2007) for an illustration and a discussion of the challenges in robustly estimating income elasticity), and benchmarking against the research literature should also help (Gillen, Morrison and Stewart (2002) for a useful survey of research findings on price and income elasticity, and also InterVISTAS, 2007).

More generally, there is always a question of whether trends which have been well established in the past will hold equally true in the future. For example, whether the strong historic link which has been established between airport demand and economic growth will continue into the future, particularly as the centre of economic gravity moves eastwards with strong passenger demand growth in south-east Asia, or whether instead it will start to weaken, as suggested in the case of car travel (ITF/OECD (2013) for a discussion of this latter point, and Smyth and Christodoulou (2011) for a review of the rather limited research evidence on market maturity in air travel).

And finally, time series econometrics is usually a less useful forecasting tool in markets where there is the possibility of material changes in the degree of competition between airports and /or airlines. The regulatory reforms of recent decades, and collateral innovations in technologies and business models, have together meant that airlines and airports often face greater competition and, correspondingly, passengers have a wider range of alternatives to choose from. In consequence, these choices have become a far more important factor in shaping airport demand over this period (although the significance of this will of course vary between locations). It is in these circumstances that choice analysis is likely to be particularly useful (ACRP (2007), and it is to this that we now turn.

Choice analysis

An option that offers the possibility to examine potential outcomes in more detail is discrete choice modelling. This is used to analyse and predict individual choices between alternatives from a finite set of mutually exclusive and collectively exhaustive alternatives. Such models have numerous applications since many behavioural responses correspond to choices within a set of alternatives. The ultimate interest in discrete choice modelling, as in most modelling, lies in being able to predict the decision making behaviour of a group of users. The technique is used to determine the relative influence of different attributes of alternatives, and differing characteristics of individuals, when they make choices (Koppelman and Bhat, 2006).

There are two basic ways of modelling such group behaviour. The first is commonly referred to as the aggregate approach and directly models the aggregate share of all, or a segment of, users choosing each alternative as a function of the characteristics of the alternatives and socio-demographic attributes of the group. The second approach is to recognise that aggregate behaviour is the result of numerous individual decisions and to model individual choice responses as a function of the characteristics of the alternatives available to, and socio-demographic attributes of, each individual. This second approach is referred to as the disaggregate approach. While the second approach can provide much more information, it is also time-consuming and costly as it requires a lot of data, difficult to obtain in the airline industry (Koppelman and Bhat, 2006). One advantage of more aggregated models is that they tend to be more robust to the impact of short term perturbations and reflect long term trends. Highly disaggregate models can thus, paradoxically, be more prone to error than simpler models.

Discrete choice models are usually derived under an assumption of utility-maximizing behaviour by the decision maker. They describe preferences and choice in terms of probabilities of choosing each alternative rather than predicting that an individual will choose a particular mode with certainty. As with deterministic choice theory, the individual is assumed to choose an alternative if its utility is greater than that of any other alternative. As a result it can forecast what share of the population is likely to choose a certain alternative.

Logit, probit or linear probability models

The first two models fit curves to the data, incorporating saturation and gradual take-off effects at the upper and lower ends, in place of the straight line fits to the data points used in linear models. Logit regression models estimate the probability of choosing a certain alternative as a cumulative standard logistic distribution function, while probit regression does the same by using the cumulative normal probability distribution. Both methods provide very similar results, but historically logit models were easier to work with and as a result have been used the most (Koppelman and Bhat, 2006). When two alternatives are taken into account binary logistic models can be used. However, multinomial logit models (MNLs) should be used in the case of more than two alternatives. The MNL structure has been widely used for both urban and intercity mode choice models, primarily due to its simple mathematical form, ease of estimation and interpretation and the ability to add or remove choice alternatives. However, the MNL model has been widely criticised because of a property to treat as independent, irrelevant alternatives. This “IIA property” implies that for any individual, the probability of choosing an alternative is independent of the presence or attributes of any other alternative. The premise is that other alternatives are irrelevant to the decision of choosing between the two alternatives in the pair. This simplification does, however, allow the addition or removal of an alternative from the choice set without affecting the structure or parameters of the model. This leads to the flexibility of applying the model to cases with different choices, which has a number of advantages. First, the model can be estimated and applied in cases where different members of the population (and sample) face different sets of alternatives. Second, this property simplifies the estimation of the parameters in the multinomial logit model and third, this property is advantageous when applying a model to the prediction of choice probabilities for a new alternative (Koppelman and Bhat, 2006).

On the other hand, the IIA property may not properly reflect the behavioural relationships among groups of alternatives as other alternatives may not be irrelevant to the ratio of probabilities between a pair of alternatives. One of the most important restrictions of the IIA property implies that introduction of a new mode, or improvements to any existing mode, will reduce the attraction of existing modes in proportion to their probability of being chosen before the change. This is likely to lead to misleading results in cases where some alternatives are more ‘similar’ than others.

A simple example is mode choice among automobile, bus transit, and rail transit, as described in Small and Verhoef (2007). The two public transit modes have many unmeasured attributes in common, such as occasional crowding. Suppose a traveller initially has available only auto and bus, with equal systematic utilities so that the choice probabilities are each one-half. Now suppose we want to predict the effects of adding a rail service with measurable characteristics identical to those for bus. The MNL models would predict that all three modes would then have choice probabilities of one-third; in reality, the probability of choosing auto would most likely remain near one-half while the two transit modes divide the rest of the probability equally between them. The argument is even stronger if we imagine instead that the newly added mode is simply a bus of a different colour: this is the famous “red bus, blue bus” example of Small and Verhoef.

A nested logit model can provide a solution here as it corrects for this by using a nested (tree) structure that allows for correlation for a subset (i.e. nest) of alternatives. As a result complex tree structures can be developed which offer substantial flexibility in representing differential ‘competitiveness’ between pairs of alternatives. A disadvantage is that the nesting structure imposes a system of restrictions concerning relationships between pairs of alternatives (Koppelman and Bhat, 2006).

An alternative and very different type of behaviour modelling is the”Kenza” approach developed by Sallier (2010). He came up with an empirical, non-econometric approach in an attempt to overcome some of the perceived disadvantages of econometric projection. Econometric forecasts require a reasonable length of times series data to provide a projection with reasonable suppression of noise in the data (or, perhaps, a panel of time series and cross-sectional data). Such long time series data are sometimes not available, or of limited use because of the impact of ‘exceptional’ events occurring during the period recorded. Secondly, any econometric model extrapolates over the future the pattern of (consumer) behaviour measured in the past. This can be considered a rather questionable assumption as future behaviour patterns may change.

Sallier therefore uses a more behavioural modelling approach in order to assess how demand elasticities might evolve in the future. His demand equation uses average ticket prices, normalised in relation to incomes (normalization value), while reflecting customer behaviour via the use of parameters operating on ticket prices (reservation price) and market penetration rates (rate of entry). Sallier assumes the parameters to be constant over time, but different from one population to another, and assumes that individuals tend to adopt the qualitative and quantitative consuming habits typical of current air travellers as soon as their income increases to levels that allow them to do so. This is a strong assumption that may not hold in reality. However, this simplification does allow Sallier to use a relatively simple and static model which he considers does not have to deal with endogeneity and time series problems typical of econometric analysis. The Kenza approach was initially developed for Airbus Industries in the late 90s and represents, today, the primary short, medium and (very) long term demand forecasting tool of Aéroports de Paris (CDG & Orly).

More generally, a developing research literature is improving our understanding of the factors which are important to shaping passenger choices between different airports (see, for example, ACRP (2013) and the Roundtable presentation by Benedikt Mandel, which outlines a model in which passengers choose between different origin and destination airports – within a regional catchment – and between competing route alternatives). The emerging evidence reviewed in the ACRP report confirms that, as expected, two of the most important factors are an airport’s effective catchment area – its accessibility to prospective passengers – and various characteristics of the level of air service offered (particularly frequency of flights).

The impact of these factors differs, as expected, between passenger segments (for example, leisure travellers are usually more willing to travel to a distant airport, but usually put less value on a high flight frequency) and passengers usually tend to prefer airports with which they have (favourable) prior experience (referred to as "airport choice inertia" by Hess and Polak (2005) and related to Levine's concept of "familiarization" (Levine (1987), in which the search costs which passengers have sunk in a familiar airport/terminal/airline provide a competitive advantage to incumbents, which is sometimes reinforced through loyalty programmes).

Airline, ticket prices are an important airport choice factor for some (but not all) market segments, and there are several choice factors (e.g. length of check in time) which appear relevant to some specific locations, but not for all. The key question for airport demand is then how these different factors impact and interact in different locations and in different market settings (ACRP, 2013) for some illuminating case studies).

Whilst the level of air service is one of the most important factors shaping passengers' choice of airport, the ACRP report found that there is far less research evidence upon the factors which determine such levels of service at different airports (ACRP (2013). This is perhaps not surprising, given the profound changes which have taken place in the airline business over the last several decades – facilitated by wide ranging regulatory reform and stimulated by innovation in both business models and technologies. Anticipating the outcome of the development of increasingly competitive markets is, by their nature, very difficult. But what this means is that in using choice models to make forecasts we need to recognise that one of the key drivers of passengers' choices – levels of service - is itself very difficult to forecast. This suggests two conclusions. First, it means that this factor – the future pattern of development of airline services – will be a very important source of risk and uncertainty in the demand forecasts for at least some airports. The second conclusion is that there will be an important role for expert guidance in reaching a view, or at least developing scenarios, on the likely future pattern of service levels. We will discuss all of this in more detail later on.

Choosing between different forecasting approaches

A number of remarks can be made in order to ensure good practice in the use of models, whatever the model employed. First, elasticities are not usually linear. That is, demand does not respond uniformly to changes in factors such as price, or quality of service, throughout the range of possible values. There is usually an S shaped curve with demand growing rapidly, after a slow take-off, and then eventually saturating. Some modelling exercises mistakenly use linear relationships hidden in their mathematics.

Demand may also be subject to thresholds. Below a certain income level, for example, an individual may rarely fly, or at least fly only on low cost services. The functions adopted to describe demand also should not fall to zero but need to assume decay to a basic service level. The demand function should be non-linear with a fat tail rather than being linear falling to zero.

Calibration of model results is a very important part of the modelling effort. That is anchoring the forecast in real world performance. LAN, for example, compares survey data used in its modelling work with real operating data. Because of difficulties in collecting data, discrete choice modelling is sometimes based (at least partially) on stated preference surveys. These have the advantage of being able to explore issues of quality of service in great detail and they give a good picture of relative advantages and disadvantages. However, they are not a reliable guide to the absolute value of an investment, or other change. In practice, the experience is that changes in preferences are more extreme in stated preference responses than they are in real life behaviour. So one should not use stated preferences on his own to estimate elasticity, or other forecasting parameters. For this purpose the scale of stated preference needs to be adjusted (typically using joint revealed preference – stated preference estimation) and the constant terms need to be corrected.

Data is always a challenge. Data sources have changed as the aviation business changes. Data on ticket sales through conventional channels, as routinely reported by IATA, is no longer adequate as direct internet sales now account for such a large share of trips – 60% in Europe – and sales through tour operators and charter flights have always been absent from the IATA dataset.

The more disaggregated modelling exercises can require very large amounts of data that is difficult and costly to acquire. The level of modelling detail required to inform a decision should be considered carefully and aggregate elasticities are a reasonable substitute for behavioural survey data in some circumstances. Network Airlines tend to find it worth investing in detailed models and data as they need to understand markets at a disaggregated level. Airports and especially large airports will find it sufficient to model aggregate demand, with less data-intensive models. When using aggregate elasticities it is very useful to cross check results between models and across countries (the survey of research results by Gillen, Morrison and Stewart (2002), the analysis and discussion in Oum, Fu and Zhang (2009) and in InterVISTAS (2007).

At the most detailed end of the spectrum, discrete choice models have the advantage of being able to examine the entire end to end journey, including access to the airport of departure and the surface transport onward journey at the destination. They are particularly useful for examining intermodal competition, between air, road (car and bus) and rail and taking account of factors that determine quality of service (ease of access, convenience of transfers, inconvenience of transferring from public transport with luggage, etc.). Lufthansa has used discrete choice models for operations in Europe for some time. It uses them to optimise operations, with a culture of optimization reflected similarly in its unusually heterogeneous fleet of aircraft, designed to match market demand closely. EasyJet and Ryan Air at the other end of the scale do not model operations. Their business model is dependent above all on price competition and cost control, factors that do not require highly disaggregated modelling. When faced with assessing the impact of building a high speed rail station at an airport, discrete choice modelling is very useful.

In summary, any good model helps understand investment and planning problems, and helps distinguish short term from long term trends. It helps identify gaps and weak points in assessment. A good model is a map to help guide decision making.

Getting the best out of the models used

Getting the best out of the models will involve, as discussed above, some technical questions to do both with the selection of the right models (that is, those most relevant to the market circumstances of the airport under consideration) and also to do with the validation and interpretation of the results of those models, drawing upon expert advice. Experience shows that it is equally important to look carefully at issues to do with the governance and organization of the forecasting work.

Research evidence indicates that these issues pose a risk of material inaccuracies to forecasts. In particular, the work of Flyvbjerg and colleagues (Flyvbjerg 2009 for an overview) studied forecasts that had been prepared for transport infrastructure projects over a period of thirty years, and across a range of different countries. That they found a track record including inaccuracies is perhaps not surprising, given the inherent technical difficulties with long term forecasts. But two other findings from this research are important in the present context. Firstly, demand forecasts tended to be positively biased – that is, they were far more likely to over-estimate demand – and thus a favourable case for investment – than the reverse. And second, the researchers were not able to detect, over the course of the thirty years of data studied, much material improvement in forecasting accuracy – despite the advances which have been made in methods, and often in data, over this period. This lead the researchers to conclude that a material part of the observed inaccuracies in forecasts were not just technical in nature but reflected two other factors. The first of these are to do with various psychological characteristics that result in over-optimism, and over-confidence in relation to favoured projects. More specifically, the work of Daniel Khaneman and colleagues (Khaneman (1994) or Khaneman and Tversky (1979)) has shown how these kinds of psychological factors can lead to biases in economic forecasting. The second factor has to do with the incentives created by funding flows and the processes needed to secure project approval; together these can create incentives to strategically overestimate demand and to overstate the positive impact of an infrastructure project. In other words, planners and managers may have a different set of organisational goals to a concept of "the public interest" – as suggested by public choice theory – or may be unable to thwart the influence of special interest groups.

The guidance provided by even robust forecasting and risk management systems can thus be overturned by the incentives created by funding flows. For example, in cases where airport charges are subject to rate of return regulation there is evidence of over-investment and higher costs (see Oum, Zhang, and Zhang, 2004). Similarly, when part or all of funding for airport expansion is provided by government there can be an incentive for a planner or an airport manager to aim for maximising funding whenever the political and economic climate provides the prospect of funds being available. This is particularly so when funding is provided by federal or multi-national (EU) institutions as increased funding has no impact on local taxation. The local stakeholders then receive potential benefits at no direct cost. In the US the Federal Government aims to minimise this effect by producing its own forecasts of airport traffic, denying financial assistance to airports where their forecast differs from the FAA forecast by more than 10%. The quality of the FAA forecasts is therefore critical (and although they are solid enough they tend to be adjusted very often to track recent trends instead of employing long term scenarios to evaluate risk) and as with any such rule, the rule will be gamed and airport forecasts aligned to maximise their chance of passing the hurdle regardless of what local risk analysis might indicate.

Over-investment is frequent in such circumstances (Niemeier (2013) and Maertens (2010) for evidence on over-investment in airport capacity in Europe). And the research evidence suggests that these incentives are sometimes (and perhaps often) reflected in misleading forecasts (Flyvbjerg and COWI (2004) and Wachs ((1990) for evidence on transport demand forecasts more generally). Some evidence specifically on airport demand forecasts is provided by Niemeier (2013). In a case study for Hamburg airport, he finds that forecasts prepared by the airport in 1996 to assess the case for investment in additional capacity significantly over-estimated aircraft movements (by over a third for 2010, for example). In part, this seemed to result from inconsistent, and implausible, forecasting assumptions on aircraft load-factors. He also finds that there is some evidence of over-optimism in the forecasts for some other German airports. More generally, however, the Roundtable discussion noted that there is relatively limited rigorous evidence available on the ex post performance of airport demand forecasts (a point also noted by Niemeier (2013) and, for the USA, in an ACRP report, which concluded that this should be a priority for future research (ACRP (2007).

There is a useful conceptual distinction to be made in this discussion between the two potential sources of bias outlined above. The first is essentially inadvertent and is a bi-product of psychological factors – in particular over-optimism and over-confidence – which in some circumstances might be considered positively beneficial characteristics of senior decision makers. The second, on the other hand, is knowingly strategic, without any obvious associated advantages. Nevertheless, these two sources of bias can overlap – and may reinforce one another - within an organization or project team. The key point here is that the research evidence shows that these types of bias can be of material importance in practice. And, correspondingly, in order to make better forecasts we need not only to make technical improvements – as discussed in the previous section – but also act to reduce the potential impact of these "optimism biases".

What steps are best likely to achieve this? Flyvbjerg and colleagues have made a range of suggestions on this (Flyvbjerg (2009) for an overview); four of these seem particularly relevant to airport demand forecasting:

- First, it is useful to engage expert, independent peer review of the forecasting work (recognizing the familiar challenges of establishing effective peer review processes).
- Second, it is useful to benchmark forecasts against comparator literature (for example, as noted earlier, Gillen, Morrison and Stewart (2002) provide a survey of research evidence on price and income elasticity, InterVISTAS (2007) provides an overview and some comparators as does Oum, Fu and Zhang (2009). To some extent, benchmarking can be seen as an approach toward the concept of "reference forecasting" proposed by Lovallo and Khaneman (2003)
- Third, there should be transparency in the development of forecasts; for example, publication of methods, peer review comments, results and benchmarks – with the aim of engaging commentary and advice from the wider stakeholder and analytical community with an interest in airport demand forecasts
- Fourth, it would be useful to aim to make provision for ex post evaluation of how the forecasts have compared to out-turn in practice.

Drawing this discussion together suggests the following emerging conclusions on steps toward better forecasts; an overarching theme here emphasises the value which can be gained from blending together quantitative analysis - based on econometric and statistical methods - and qualitative analysis, drawing upon expert assessment.

First, it will usually be worthwhile to use econometric and statistical analysis, of the kind described above and elaborated in the Roundtable papers, to help understand – in quantitative terms – the key drivers which have shaped demand in the past; and then to use this as a starting point to forecast demand in the future. Decisions on the relative merits of time series or choice analysis should be shaped by an assessment – preferably guided by expert advice - of prospective market circumstances; but sometimes a two-stage approach will provide the best solution – using time-series econometrics to develop forecasts for a broadly defined market and choice analysis to develop forecasts for specific airports within this market (Airports Commission (2013) for an illustration of this kind of two stage approach).

Second, it will be useful to draw upon expert guidance, perhaps using formal elicitation methods (such as Delphi) to make best use of this expertise. Expert guidance will be particularly helpful in the choice of forecasting methods and in advising on scenarios for the future development of airline networks, and the implications of this for competition and service provision at different airports. And expert advice will also be important in the interpretation of the emerging analytical results and in the development of forecasts from these results.

Third, it will be important to constrain the risks of optimism bias. Here expert guidance on emerging forecasts – as described above - and independent peer review will be helpful, together with transparency and engagement with the broad range of stakeholders with an interest in the forecasts, and benchmarking of the forecasts to the existing research literature.

Finally, we need to recognise that however successfully all of the foregoing is carried out there are likely to remain material risks and uncertainties in even the best airport demand forecasts. The key issues which this raises are then, firstly, how these risks and uncertainties should best be measured, and in this way recognised, in the presentation of airport demand forecasts. That is, how we can be (appropriately) "more modest". And secondly, how these risks and uncertainties are best taken into consideration in the planning of airport infrastructure investment. It is to the consideration of these issues to which we now turn.

Dealing with risk and uncertainty in airport demand forecasts

The basic problem with airport demand forecasts has been the large surprises which have quite often arisen – with demand sometimes falling well below expectation (although occasionally, instead, with out-turns well above forecast). These surprises matter because airport infrastructure often (although not always) involves large irreversible investments, also with long lead times. This can mean that a big gap between forecast and out-turn either results in resources being wasted on under-utilised capacity or, alternatively, results in congested facilities which lead to delays and reduced service quality (with likely financial and resource pressures in either case).

The first part of this report discussed ways of tackling this problem by "making better forecasts" – that is, improving the quality and accuracy of airport demand forecasts. The discussion of the papers at the Roundtable suggested various steps – both technical and institutional – which together might help to bring significant improvements. But this discussion also concluded that, even with these improvements, there would nevertheless still remain significant risks and uncertainties. In other words, material risk and uncertainty appear to be an intrinsic characteristic of airport demand forecasts (at least for the foreseeable future).

In view of this, it wouldn't perhaps be surprising to find that a discussion of risks and uncertainties formed an important part of the presentation of airport demand forecasts. In practice, however, this is typically not the case. For example, a study of airport demand forecasts in the USA found that this is "an often neglected aspect of forecasting" (ACRP (2007). Furthermore, where risk and uncertainty is considered, the treatment is often relatively simplistic (for example, the presentation of rather arbitrary high and low scenarios alongside a central forecast – ACRP (2007). And, perhaps for this reason, the risk analysis is rarely used in investment planning (ACRP (2012) which notes, again in the context of the USA, that "high and low forecasts have little input into subsequent planning efforts"). The position in Europe seems to be essentially similar, Burghouwt (2007).

So there appears to be an important paradox here. On the one hand, risk and uncertainty are widely recognised to be an important characteristic of airport demand forecasts, with potentially important consequences. On the other hand, these risks and uncertainties are often not subject to serious analytical consideration, nor are they effectively recognised in investment planning. The discussion at the Roundtable suggested some reasons for this paradox, and also suggested some steps toward helping to resolve it. Essentially, the paradox is a reflection of a particular approach to infrastructure planning which frequently comes to be adopted – what we might call a "one-shot" approach. Flyvbjerg noted in his research on major transport infrastructure investment that, "often there is "lock in" or "capture" of a certain project concept at an early stage, leaving analysis of alternatives weak or absent" (Flyvbjerg (2009). A UK study similarly described this process as "starting from solutions rather than from problems" (Eddington (2006). Essentially, what happens in this "one-shot" approach is that the planning process quickly becomes focused upon a preferred proposal. This is then often subject to extensive testing (against traffic forecasts, financial performance, cost-benefit results, environmental impact, and so on), but with relatively less extensive consideration of possible alternatives. There are a number of well understood reasons why infrastructure planning might develop along this path (including some of the factors discussed earlier which facilitate "optimism bias"), and some suggestion that the traditional approach to master planning might have provided additional impetus in the case of airports (ACRP (2012) or Burghouwt (2007). In the present context, there are two relevant conclusions. The first is that once a "one-shot" approach has come to be adopted, then - actually - an analysis of risk and uncertainty doesn't really add much value in practice (other, of course, than to tell you that you shouldn't be using a one-shot approach). And, in line with this, the Roundtable discussion noted that the presentation of a wide risk margin on forecasts was sometimes not seen to be helpful to senior decision makers, or particularly welcomed by them. The second conclusion follows directly from this. In circumstances where there are material risks and uncertainties to forecasts then a "one-shot" approach to infrastructure planning is quite likely to prove less efficient than an approach which, firstly, aims to recognise risks and uncertainties. And, secondly, then uses this recognition as a basis for building into the infrastructure planning process ways of controlling, diversifying and reducing the (adverse) impact these risks. And thirdly, in this way, aims to improve the efficiency (and expected value) of infrastructure investment.

The Roundtable discussed how risks and uncertainties might best be recognised and (where feasible) quantified and how risk management measures might best be developed and their prospective value assessed. We will consider each of these in turn.

Recognising and quantifying risk and uncertainty

A key consideration in recognising risk and uncertainty in forecasts is whether or not we can reasonably assess the probability that a particular risk will materialise in practice. A useful conceptual distinction here is between, on the one hand, events where we have a pretty good idea of the chance (or probabilities) of different outcomes; and on the other, events where we have little realistic idea of the chances of the different outcomes or even, perhaps, what those outcomes might be (Kay (2009) for a discussion of these issues).

Events falling in the first group are most readily illustrated by games of chance; for example, whilst we don't know what score will result from a fair roll of a dice, we do know that the chances of getting a six (or any other pre-specified score) are one in six. Events like this are sometimes called "pure risks"; we don't know what outcome will arise in practice, but we do know the chances (or probabilities) of the different possible outcomes. And, correspondingly, we can work out the likely returns to different courses of action – different investment strategies for example – and make decisions in the light of this analysis.

Events in the second group are most readily illustrated by completely unforeseen catastrophes – the "unknown unknowns" – such as the Great Recession in the early part of this century or the influenza pandemic a century earlier. Events of this type are sometimes referred to as "Knightian uncertainties". Not only would it have been impossible to make any useful assessment of the probability of these events occurring immediately prior to their emergence, it's unlikely they would even have been considered as active possibilities. And in these circumstances, it is not possible to factor such events into decision making in any quantified or systematic way.

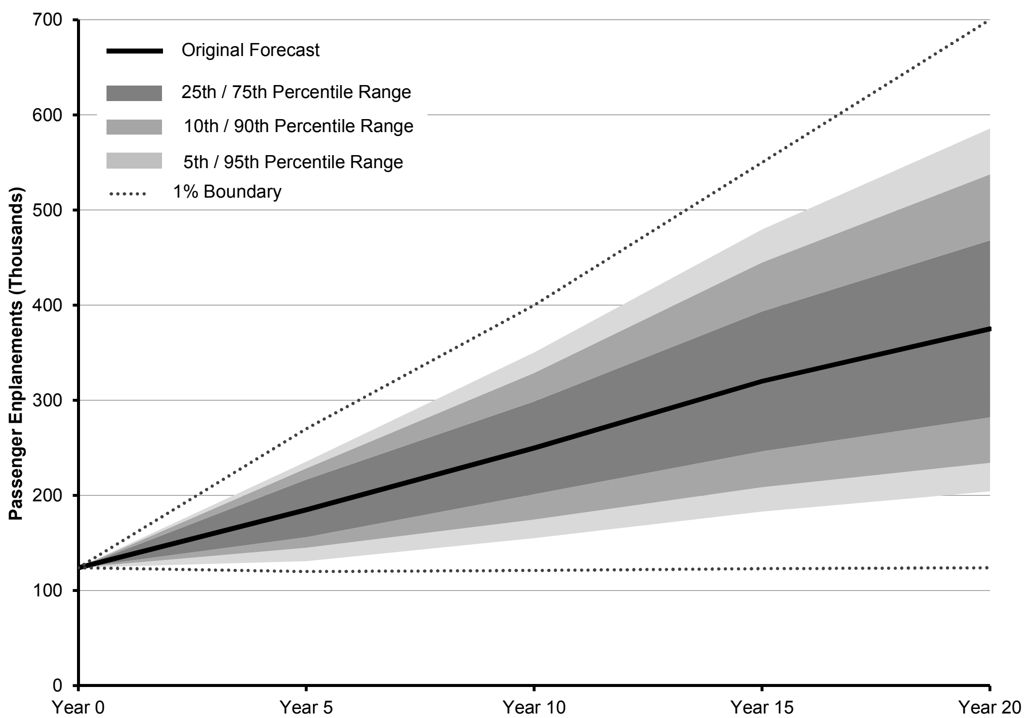
This distinction is thus rather important because the two different types of event have quite different implications in terms of how they are best analysed and recognised in airport demand forecasts. In practice, however, the events in which we are interested will often lie somewhere between the polar concepts of "pure risks" and "Knightian uncertainty", as we discuss in more detail in what follows. For this reason, Ian Kincaid and Nicole Geitebruegge decided to use the terms "risk" and "uncertainty" interchangeably in their Roundtable paper.

Quantifiable risks

The risks and uncertainties which are most readily quantified are those which are captured directly in the econometric and statistical models which underpin airport demand forecasts. (again see the Roundtable paper by Kincaid and Geitebruegge). Risk registers, examining the impacts of past events from the perspective of different parts of the airport business, are the first step in building risk awareness. For some variables, such as GDP, risk can be reflected in forecasts by looking at deviations from trend (recorded in historical data) and running the model many times (Monte Carlo modelling) to generate probabilities of deviation from the forecast in the future. This produces confidence bands around the central forecast.

Monte Carlo analysis has become much more accessible to general users thanks to the availability of specialised statistical software packages (ACRP (2012). In essence, the degree of precision which is achieved in tracking past trends can be used to assess the likely margins of risk and uncertainty associated with the model's forecasts of future trends. Of course, allowance also needs to be made for the similar margins of risk on the (input) forecasts of the key drivers of demand growth – e.g. future economic growth, fuel prices etc. Combining these various risks together, using techniques such as Monte Carlo analysis, enables a quantified margin of risk to be established around an airport demand forecast. Figure 1.1 provides an illustration of this approach – the chart shows a central forecast and also forecasting ranges which cover between 50% and 99% of estimated outcomes (ACRP, 2012) for a discussion of methods; this report includes some practical applications as does Airports Commission (2013).

Figure 1.1. **Illustrative prediction intervals**



Source: "Addressing Uncertainty About Future Airport Activity Levels in Airport Decision Making", ACRP Report 76, 2012.

This kind of quantified measure of risk and uncertainty can prospectively be very helpful in making investment decisions (as we discuss further below). But we also need to recognise that what is being quantified here are the risks and uncertainties which are "in the model"; that is, in a sense, those which would arise "if the future were to look similar to the past". The question this raises is whether there might be changes in circumstances which lead to a materially different range of outcomes and, if so, how this should best be recognised in our forecasting analysis.

Subjective probabilities

In practice, there are a range of factors that might mean that "the future will look different to the past" – including changes in technologies and business models, climate change and associated policies, exceptional economic or social events, unexpected changes to consumers' tastes, and so on.

Whilst many of these risks cannot be “included in the model” – at least completely – not all of them are pure “unknown unknowns”. In many cases there is a foundation of emerging research evidence and a body of expert opinion upon which to draw. This expertise might be best accessed using the kinds of formal elicitation techniques – such as Delphi – discussed earlier (ACRP (2012) for a discussion).

In some cases the research evidence may be considered sufficiently strong to formulate subjective probabilities of particular events (for example the prospective impact of developments in communications technologies on the demand for business travel). Again this provides a quantitative measure of risk which can be factored into investment planning, although a measure whose provenance is less secure than the quantitative analysis of past trends discussed in the preceding section. And other variables can be factored in according to the impact of specific events in the past.

In other cases, where the evidence is less strong, the research expertise might be used to develop scenarios – alternative future paths of development grounded in expert opinion – against which investment proposals can be tested Even though we can’t say, with any useful certainty, what is the likelihood of the different scenarios the range of outcomes is useful in determining the spectrum of possible outcomes (Chapter 2 by Kincaid and Geitebruegge).

In some cases, the resulting projection surface may be so broad as to appear to give no guidance on future demand, but the exercise directs attention to providing capacity in as flexible manner as possible. Scenarios thus not only shed light on “how much” but “what kind of” capacity may be needed in the future. Even when Monte Carlo modelling and scenario analysis produces such wide bands that they are no use as a forecast, they do reflect the real risk and uncertainty that exists. This should be acknowledged, admitting that forecasting with precision isn’t possible. And then using this analysis as a basis for developing methods to control risks, where feasible; and to reduce and diversify their adverse impacts, in the circumstances where the risk is realised in practice.

Unknown unknowns

Beyond this lie the pure “unknown unknowns”. These are the types of event for which we cannot estimate any kind of probabilities, whether by using objective data analysis or subjective expert opinion. However good a map modelling provides, this kind of “Knightian uncertainty” cannot be incorporated, by definition. This kind of uncertainty concerns Nasim Taleb’s Black Swan events, something never so far experienced. Such events simply cannot be factored into forecast scenarios as they cannot be defined. However, the process of building scenarios to map out the space bounded by quantifiable risks creates an appreciation of forecasts that prepares decision-makers for responding to uncertainty.

Scenarios can be built to test the sensitivity of central forecasts to upside and downside risks that can be identified, as described above. For example, although no one can predict the GDP in 10 years or regions of political instability in 20 years, scenarios can be built around the occurrence of deviations from long term trends in the past. Similarly the frequency of events such as outbreaks of new virus strains and their impact on travel can be modelled. And as events such as the outbreak of SARS and volcanic eruptions under heavily used flight paths occur, what were once Black Swans become more identifiable risks. Similarly, whilst economic downturns are regularly factored into scenarios, the size of the economic crisis of 2008 was unprecedented since the Great Depression and widely thought more or less impossible with today’s financial institutions. Recessions of this scale are now likely to be factored into forecast scenarios as an extreme but plausible risk.

Risks more specific to aviation markets include airline bankruptcies and airlines moving hub operations out of an airport. What is of relevance in our present context – that is, forecasts for long term infrastructure – is the impact of these events over the medium/long term, that is, beyond the immediate shock effect. Thus, whilst origin-destination traffic tends to bounce back from shocks, transfer traffic does not usually return when an airport loses a hub operation. Examples include Zurich, Budapest and

Lambert St. Louis following the bankruptcies of Swissair and Malev and the decision of American Airlines to consolidate hub operations elsewhere.

In a world in which the number of hubs is probably likely to continue to fall (reflecting a range of factors including the legacies of the regulatory era and of early network development together with developments in both technologies and business models) then the loss of hub status is not usually recovered (Redondi, Malighetti and Poleari (2012). Such events are towards the more catastrophic end of the spectrum for airports. Unexpected entry can have a positive impact of a similar scale (Chapter 2 by Kincaid and Geitebruegge). Whilst, as noted earlier, research evidence to guide forecasts of the future development of airline networks and airport competition is still evolving (ACRP (2013), expert advice can be used to help analyse the problem in terms of scenarios.

This still leaves the pure “unknown unknowns” - events which may well not even be in the scenario analysis, because ex ante they wouldn’t readily be considered. In a sense, there is not much that can really be done about this. However, event analysis could give an indication of the incidence of unforeseen incidents in the past and their impact, and particularly whether these impacts where essentially transitory or whether longer term in nature. Taken together, this might provide some indication of the potential importance of making provision for the unforeseen.

Drawing the discussion together, this suggests advantages to an approach which blends together the quantitative and the qualitative. An approach which first uses techniques, such as Monte Carlo analysis to get quantitative measures of the risks and uncertainties, which are “in the model”, using econometric and statistical analysis of past data. But an approach which also recognises that a model which successfully fits the past may not equally fit the future, and which uses expert opinion – perhaps codified using formal elicitation techniques – to consider whether and how the model’s forecasts should be re-interpreted. In some cases, there will be a sufficient research base to develop useful subjective probabilities to supplement, or substitute, those suggested by the model. In other cases, where uncertainties are greater, then expert opinion can help develop plausible alternative scenarios, even if it is not possible sensibly say which, if any, of these scenarios is most likely to happen in practice. (see, for example, UK Airports Commission (2013) for an illustration of an approach which uses both quantitative and qualitative analysis of risk and uncertainty).

In any event it will be important to be transparent about which risks are included in the quantitative analysis (and which are not) and the methods used to estimate these. And to be similarly clear about the use of subjective probabilities (and the provenance for these) and the evidence underpinning scenario development.

The main purpose of this analysis, as noted earlier, will be to help develop investment strategies which aim, where possible, to control, to diversify, and to reduce the negative impact (or vice versa) of risks and uncertainties - and in this way to improve the overall efficiency of infrastructure investment. This is the topic which we consider in the final part of this paper.

Before that, however, we will look in a bit more detail at one particular risk – future airline network development and the implications for competition between airlines and airports – which has been identified as a particularly important risk for airport demand forecasts (ACRP (2013) or Burghouwt (2007) and on which there was an extensive discussion at the Roundtable.

Airport demand forecasts and airline network development

As the development of Ahmedebad airport illustrates, many new airports have been planned as hubs, but it is airlines rather than airports that make the choice of where to locate hub operations. Heathrow serves as the hub of British Airways, while Copenhagen fulfils the same role within the SAS network. No network carrier operates hub activities at Gatwick, despite its 35 million passengers a year, while Copenhagen is a hub with half that number of passengers. As the markets of the United States and Europe have matured, and new airline business models, notably low-cost carriers, have become more important, then the number of international hub airports has decreased.

According to Redondi, Malighetti and Paleari (2012), 37 worldwide airports were dehubbed over the period 1997-2009. These airports did not recover their original traffic and dehubbing generally seems to be irreversible. When a network carrier stops operating hub activities at an airport it is not usually replaced by another network carrier but instead by low cost carriers (Redondi, Malighetti and Paleari (2012). This can leave airports with expensive infrastructure suited for transferring passengers but instead hosting low cost carriers solely operating point-to-point flights and looking for more basic infrastructure provided at low airport charges.

When planning a greenfield airport, such as Milan Malpensa, it is therefore usually advisable to focus on origin-destination (O-D) traffic rather than transfer traffic. An option is to include some flexibility in the design that allows for implementing infrastructure to support hubbing activities at a later stage (recognizing that greenfield airports are relatively unusual in Western Europe and North America, where expansion more usually adds to existing capacity).

Another important issue is what to do with existing airports in the region when opening a new one. Many examples have shown that when the new airport is located further from the urban area, airlines are reluctant to move (ITF 2014). Moreover, even if the existing airports are closed, or if airlines are forced to move, this might initially result in fewer passengers as a consequence of the longer travel distance to the new airport (especially if there are other alternatives available). If the new airport charges are higher than the old ones this might also lead to negative effects for both the airlines and the passengers. At hub airports, higher airport charges are likely to particularly affect transfer traffic as transfer passengers usually have viable alternatives through other hubs and are usually price sensitive.

As Redondi, Malighetti and Paleari (2012) concluded, competition among hubs can be fierce, even on the global scale, since airports located in different continents often compete for the same O–D markets – although switching costs (to both airlines and their passengers) and, in some cases, bi-lateral constraints can both act to dampen the strength of competition. Therefore, new (local) regulations, such as airport taxes, could affect hub competition on a much broader scale. Experts at the Roundtable agreed that a government policy aimed at forcing its national carrier to move part of its hub operations to a new airport would be a risk. Although dividing international connections between a country’s two largest urban areas might seem logical from the point of view of establishing an immediate market for a new airport, economic network theory shows it is likely to be costly. Due to the existence of economies of density, scale and scope, a mono-hub-and-spoke network is usually more efficient than a dual-hub-and-spoke network. Spreading a hub operation of a single carrier over two airports within the same metropolitan area, generally turns out not to be feasible. The hub carrier will not be able to serve the same amount of connecting markets as would be the case with a single hub. By splitting the hub operation over more airports, the carrier will lose economies of density and is likely to lose market share in the connecting market because less connections can be offered. In addition, the carrier will need to duplicate at least part of its short-haul network at both hubs. Long-haul services can always be made more profitable by simply moving them from the secondary to the primary hub so long as slots are available (Burghouwt 2013). Furthermore, a government policy aimed at spreading an airline’s hub operations over two airports would also run counter to passengers’ preferences for using a familiar airport (as noted earlier, described as “airport inertia” in Hess and Polak (2006). Some similar issues can arise from regulatory constraints on hub development, such as slot regulation.

These conclusions are supported by recent research in the USA which studied airlines’ choices in multi-airport regions (see ACRP, 2013). The research found that airlines prefer to concentrate services at as few airports in a market as possible. The benefits of service concentration at a particular airport – as outlined above – are regarded as central to the achievement of legacy and network airline business models.

Discussion remains about what would be the optimal scale for a hub. De Wit (2012) states that a particular hub's viability can only be defined within upper and lower boundaries. At the lower boundary, a minimum size of hub origin and destination (O&D) markets, in terms of population and prosperity, is required to guarantee the relatively high yield from direct air services at the hub as compensation for the lower yield from the indirect air services provided to transfer passengers. These transfer passengers need to be collected by short-haul flights, which are necessary to feed the profitable long-haul flights. The larger the hub the larger the indirect market that can be served, but at the upper boundary, hubbing comes with a growing average cost as the intensity of the connection waves increases. There do appear to be dis-economies of scale as operational complexity and vulnerability to interruption grows (de Wit, 2012).

In any event, network carriers sometimes face capacity constraints at their primary hub airports. They may therefore decide to open a secondary hub in order to accommodate market growth, referred to as overflow hubs (for example, we discuss the case of Lufthansa in the next section). In most cases, these overflow hubs lack any natural advantage in the origin-destination market compared to the primary hub. Therefore the network airline generally serves the smaller intercontinental destinations solely from the primary hub, while serving the large volume destinations from both hubs.

If total demand for these destinations allows for daily service from multiple hubs, network airlines can achieve advantages in frequency of service by synchronizing the flights to the same destination from both hubs so as to serve destinations at different times of the day (Burghouwt, 2013). It should also be noted that many of the current network carriers are the result of mergers. This means that bilateral agreements, historical ties to certain countries and airports (with some corresponding differentiation in passenger characteristics), and passenger preferences for a familiar airport together often play a role in sustaining multiple hubs, at least for a time. Finally, in some cases, the current hybrid aviation regime[1] may force airlines to operate long-haul services out of multiple hubs even if, from a network point of view, consolidation on a single hub is more attractive (Burghouwt, 2014).

Examples of European multi-hub network configurations

Although political pressure and pressure from labour unions, especially with merged airlines, have played a role, it is important to note that all the European multiple hub networks that have emerged are a result of the network carrier's strategy, rather than regulatory conditions imposed by governments.

The only possible exception might be Air France KLM's complementary hub strategy, as the Dutch government imposed a condition in the Air France KLM merger agreement that assured that KLM's hub in Amsterdam would not be dismantled in the eight years following the merger. Since 2012 Air France KLM has had full flexibility to adjust its network but it continues to operate more or less as separate airlines within one group, each operating their own hub-and-spoke networks. To some extent this reflects differences in traditional business and cultural ties to overseas markets between France and the Netherlands and associated differentiation in passenger demand characteristics (Burghouwt (2013), together, perhaps, with passenger preferences for a familiar airport.

A somewhat similar story holds for IAG in which British Airways continues to operate its hub-and-spoke network from London Heathrow, while Iberia does the same from Madrid. Here the complementarities seem to be even clearer. British Airways and London have a historical focus and comparative advantage with regard to the North American market, while Iberia and Madrid have the same regarding Latin American markets. Before the merger, both British Airways and Iberia individually operated a dual-hub-network within their home countries for some time. Due to capacity as well as regulatory constraints at Heathrow, British Airways decided to move part of its short haul network, as well as some international connections, to Gatwick. However, this "dual hub" strategy undermined the feeder system of BA's long haul flights at Heathrow and as a result it moved all its hub operations back to Heathrow. In looking at options for the expansion of airport capacity in the south east of England, the UK Airports Commission has concluded that a dual hub strategy would probably not be viable for either a carrier or a network airline (Airports Commission, 2013).

A similar story held for Iberia. It operated a Barcelona hub because of capacity constraints at Madrid; in addition political rivalry between the Generalitat in Catalonia and the central government in Madrid may also have played a role. However, as soon as additional capacity at Madrid became available, Iberia consolidated the entire hub operation at Madrid, dehubbing Barcelona in 2005-2006. Ever since, Iberia operates all long-haul services from Madrid and none from Barcelona (Burghouwt, 2014).

Lufthansa operates a multi-hub network constructed around its primary hub at Frankfurt; as many as five secondary or tertiary hubs can be identified. Three of them - Zurich, Vienna and Brussels - used to be the main hub within their national flag carriers' network before these were acquired by Lufthansa. Because of their historical extensive feeder network, potential differentiation in travel patterns (reflecting their differing historical trading patterns) and central geographical locations within Europe, they all retain a small 'natural' advantage, in at least some markets, over Frankfurt. Their network incorporation shows a similar, "complementary" pattern as Amsterdam and Paris (or London and Madrid), although to a far less pronounced extent as SwissAir and Austrian Airlines have become progressively consolidated into Lufthansa; and they similarly benefit from passenger preferences for a familiar airport. A different story holds for Munich and Dusseldorf which have virtually no unique networks compared to Frankfurt, but mainly play a role as 'overflow' hubs. As a result, only in markets with a high demand between Europe and long-haul destinations (such as New York JFK and Dubai), does Lufthansa provide a direct, non-stop service from both Frankfurt and also Munich and Dusseldorf (although the latter is a tertiary hub with only a weak feeder system, which in part reflects peak hour capacity constraints (Burghouwt (2013).

The development of the network of Europe's fourth largest network carrier Alitalia also provides some interesting insights. It has operated a hub-and-spoke network from Rome, but changed to a dual-hub network in 1998 when the newly developed airport Milan Malpensa opened. The original plan was that foreign airlines serving the existing airport Milan Linate would move their operations to Malpensa, making the latter the main international airport for northern Italy and leaving Milan Linate as more of a domestic, short-haul facility. However due to the fact Milan Malpensa is located 50 kilometres outside Milan, while Linate is only 10 kilometres away from the city, many airlines were reluctant to move. In response to this, the Italian government proposed to put in place Traffic Distribution Rules to achieve a shift from Linate to Malpensa. However, the European Commission rejected the government's initial proposals (on grounds of discrimination); furthermore, the municipality of Milan wanted Linate to continue to offer high quality European connections to its citizens. In consequence, it was eventually decided that some European flights would still be permitted to operate from Linate (Redondi (2013) for a more detailed account). This resulted in two consequences; first, passengers travelling between Milan and European destinations often preferred to use the more convenient (and familiar) Linate, thus diluting traffic on feeder flights to Malpensa. Second, some inter-continental passengers also preferred to continue to use Linate – connecting via a major European hub – rather than incur the higher access costs in taking a direct flight from Malpensa (Redondi, 2013). The result was that the disappointing performance of Malpensa services – among other factors – led to Alitalia withdrawing inter-continental services from Malpensa in 2008 to concentrate them at its hub in Rome (Redondi, Malighetti and Paleari, 2012). It is also interesting to note that traffic growth for the Milan airport system over the period was lower than for the rest of the Italian market, despite rapid growth at the third Milan airport – Bergamo – which principally serves LCCs. It seems possible that the unsuccessful attempt to establish a hub at Malpensa may have damaged market growth for the Milan airport system as a whole (Redondi, 2013).

Markets for airports in proximity to intercontinental hubs

Large, prosperous cities provide sufficiently large markets for direct long-haul service to other large cities that can compete with services via nearby hubs, particularly for business travellers. Such cities are also attractive for long distance connections from hubs abroad, especially where access to the national hub airport is constrained. The market may also be large enough to support hub operations for regional, medium-haul international flights. Whilst a national airline will not split its hub operations across more than one hub unless forced by capacity constraints, a foreign owned network airline might consider establishing a hub in a secondary airport if it provides access to the national market and is located in a geographically strategic location for its long distance routes. The possibilities available to such airlines depend on the conditions attached to air service agreements; granting access under such agreements to secondary airports may be less contentious than granting access to the national hub airport where competition with the national flag-carrier is more direct. Where airports compete for traffic, airlines determine their network structures on the basis of slot availability and relative prices and passenger demand characteristics. To model the decisions of airlines in developing hub operations is not straightforward, not least because there are relatively few research studies which have provided robust, generalizable evidence on the factors which shape network development (ACRP (2013) for a discussion and also evidence from a series of case studies in multi-airport regions in the USA).

In modelling the user benefits, the generalised costs of travel (monetary and monetised time costs combined) need to be compared for alternative routings. Better connectivity and higher overall benefits might be available through the growth of feeder services through a main hub rather than direct services from a new secondary hub. This can be a particularly effective strategy when the main hub is in a city with multiple airports and most domestic flights are operated out of one of the non-hub airports – a common pattern where a large new hub airport has been developed to replace an airport closer to the city centre where expansion was no longer possible (ITF 2014). Developing more feeder services to the hub, or reinstating long-haul flights at the older airport may be a cost effective alternative to developing a second international hub airport in a secondary city.

New aircraft technology - for example, the introduction of the Airbus A350 and Boeing Dreamliner that are designed to provide long-haul O-D services in smaller planes at lower cost or the Bombardier C series which has the range and fuel economy to provide hub bypass for thin, medium distance routes - may increase the opportunities for development of secondary hubs by decreasing the multihub market threshold by allowing the hub carrier to serve smaller markets profitably (Burghouwt, 2014), although these developments will also enable thinner routes to be added to existing primary hubs. Such changes are particularly difficult to predict, as discussed already.

Connectivity to affordable international services for passengers in cities distant from the primary national hub airport can be facilitated, in most cases, by increasing feeder services to the hub airport (as opposed to an alternative airport in the capital). The size of the O-D market, rather than the potential hub market, is what will determine the feasibility of a second major airport.

Airport capacity expansion in south-east Korea

Lessons from deregulation in Europe include a rapid rise in low cost carriers serving many new routes from secondary airports, both domestically and internationally. A similar development might be expected in Asia if deregulation continues. In these circumstances, many of Korea’s smaller airports would likely see their number of direct international connections increasing. In order to assess the implications of this development, it would be useful to study the feeder network at Incheon in more detail to look at the final origins/destinations of its passengers. That is, it might well be the case that passengers who currently travel by train to Incheon before boarding an international flight would switch to a direct flight from a local airport if/when one is offered by a low cost carrier. This leads to diverted demand and will have direct consequences for the demand for airport capacity at the local airports. As such, there is then a question of how capacity expansion at these local airports would compare, as a solution, with constructing a new airport. This, in turn, is likely to depend on which types of airline are likely to demand more airport capacity.

European experiences suggest that it is unlikely that a full service airline would be willing to operate an intercontinental hub in the south-east region of Korea, as it would face a comparative disadvantage compared to competing full service airlines operating hub activities in Seoul (which provides the largest O-D market in Korea as well as the largest airport capacity).

As a result, it is quite possible that better connectivity and higher overall economic benefits would be achieved through the growth of feeder services through Incheon rather than direct services from a new airport in south-east Korea. In order to assess whether this is the most efficient solution, the overall (net) economic benefits of alternative routings need to be compared in the modelling.

Seoul is located only 330 km away from Busan and can be easily reached by high-speed train. Although it currently requires a transfer to subway or bus to reach Incheon from Seoul station, an extension of the high-speed line directly linking Incheon to the rest of the network is currently being built and is scheduled to open at the end of 2014. Consequently, passengers departing from regions such as Busan, Gwangju, and Daegu will be able to connect both more quickly and less expensively (compared to short-haul feeder flights) to connecting flights at Incheon International Airport.

Nevertheless, Korea's second largest city, Busan, currently faces capacity constraints as its runway only provides around 60% of the normal runway capacity both due to the proximity of mountains and because of the military use of the airport. Airport expansion could therefore be considered if demand forecasts show that there is enough local demand. It seems, however, more risky to focus on providing capacity for intercontinental transfer passengers. As mentioned above, the intercontinental hub operations of Korean Air and Asiana at Incheon airport, which can now be accessed from Busan via an efficient high speed train connection, makes it unlikely that any airline would be interested in operating a hub for intercontinental flights at Busan airport.

International experience thus seems to suggest that Korea's policy of focusing on the main hub and increasing its catchment area through better feeder services is likely to be more efficient than seeking to open a secondary hub. For example, in Europe both the Spanish flag carrier Iberia and its Italian counterpart Alitalia each operated a dual hub strategy across their two largest domestic cities for a while. However, in both cases it turned out to be rather inefficient, and commercially unsuccessful, and both airlines decided to operate a single hub in their capital cities. To put this into perspective, the distance between the cities is about 500 km in both cases, broadly 50% further than the distance between Busan and Seoul. The continued operation of complementary hubs in both Paris and Amsterdam by Air France - KLM tells a slightly different story, one driven by some degree of segmentation in the relevant markets (see Burghouwt, 2013) and, perhaps, the preferences of passengers for a familiar airport; as, similarly, does the case of the hubs operated by IAG in London Heathrow and Madrid. All of this illustrates the importance of a case by case analysis of market conditions.

Nevertheless, most empirical and theoretical studies have shown that concentrating activities on the primary hub is generally the most efficient policy from an economic and commercial perspective, a conclusion supported by recent research in the USA into airlines choices in multi-airport regions (ACRP, 2013).

Summarising, it seems unlikely that a full service carrier would be interested in operating an international hub in the south east region of Korea. On the other hand, as noted previously, European experience shows that low cost carriers might rapidly open new routes, as soon as the regulatory framework allows them to do so. This might suggest that expanding local airports located close to urban areas may provide better value, in economic terms, than building a large new airport in a less accessible area. This latter option could result in longer travel times to the airport, and lower demand, as well as higher construction costs, although local environmental impacts will also need to be factored into the equation.

Overall, south east Korea can be expected to provide sufficiently large markets to make viable direct services to other large cities, both domestically and internationally, that can compete with services via the hubs in Seoul, Tokyo and Shanghai, particularly for business travellers. These flights might be offered by Korean full service carriers as well as low cost carriers. European experiences have shown that in short haul markets low cost carriers can rapidly expand to market shares exceeding 33% in some instances.

In addition, if local demand in the region is sufficient then it is possible that foreign full service carriers – such as Emirates – might choose to offer long haul flights to both Incheon and south east Korea (as part of a strategy to offer a high frequency and capture high yield business class passengers).

Finally, the market may be large enough to support hub operations for regional, medium haul international flights. A foreign owned network airline might consider establishing a regional hub if it provides access to the national market and if it is located in a geographically strategic location for its long distance routes. However, the possibilities available to such airlines depend on the conditions attached to air service agreements. Granting access under such agreements to secondary airports may be less contentious than granting access to the national hub airport where competition with the national flag carrier is more direct. Where airports compete for demand, airlines determine their network structures on the basis of slot availability and prices as well as passenger demand characteristics. As noted earlier, however, there is at present relatively limited research evidence to underpin models of airlines decisions in the development of hubs and networks (see ACRP (2013) for an overview) and forecasts of this need to be based on alternative scenarios developed with expert guidance, not least because new aircraft technologies may well shift the balance of these choices in the future.

Airline network development and airport demand forecasts

Drawing this discussion together, the research evidence shows that levels of air service are often an important factor in shaping passengers' choices between different airlines and airports and can therefore be an important factor in shaping airport demand. But airlines' business decisions – which shape service levels – are less well researched or understood, particularly in relation to network development. The discussion at the Roundtable, both of research findings and recent experience, suggests the following emerging conclusions.

First, most theoretical studies of airline networks suggest that it is usually beneficial – in economic and commercial terms – for a network airline to focus its operations in a particular market on a single hub (and in this way get the best value – in terms of costs and service levels – out of exploiting density economies). Nevertheless, some studies suggest that a multi-hub network may sometimes prove more efficient, perhaps in situations where there is strong geographic segmentation between different parts of the market, together with sufficient O-D demand. And it is also possible that at high levels of traffic there might be various diseconomies of larger hub size which start to off-set the benefits of density economies.

Recent empirical research in the USA (ACRP, 2013) provides some support for these findings. In particular, the study found that airlines prefer to concentrate services in a particular region at as few airports as possible. The benefits of concentration at a particular airport are regarded as central to the achievement of legacy and network airline business models. Nevertheless, larger carriers will sometimes operate at more than one airport in a large metropolitan region if the demand conditions provide for this. More generally, the provision of airline services at alternative airports is usually found to be shaped by the suitability of these airports for the provision of niche services by low cost carriers. These carriers tend to focus on point to point traffic, and this means that they usually choose to serve a region through a single gateway.

Experience in Europe also supports these emerging conclusions, although in a slightly more nuanced way. This experience shows a number of unsuccessful attempts to establish dual hubs (in particular, Rome-Milan Malpensa, Heathrow-Gatwick and Madrid-Barcelona). This lack of success seems to reflect both the advantages of a single hub in exploiting density economies, perhaps coupled with passengers' general inertia in switching away from a familiar airport; and additionally ,in the case of Milan, competition from a well-established and highly accessible short-haul airport at Milan Linate. However, the European experience also shows a number of examples of legacy hubs – that is, hubs inherited from the regulated era – which have been successfully sustained in a multi-hub network (for example, Paris-Amsterdam, London-Madrid or Lufhthansa's configuration constructed around its primary hub at Frankfurt). The continuing success of these multiple hubs seems in many cases to reflect a degree of complementarity, with relatively strong geographic segmentation in their markets (typically the various partner hubs are located in different European countries with different historic patterns of trade and business connections, see Burghouwt (2013), perhaps also reinforced by passengers' general preference to continue using a familiar airport. However, in some cases – Lufthansa's secondary and tertiary hubs at Munich and Dusseldorf – their role seems primarily to offer direct services to only the most popular long haul destinations in addition to the primary hub at Frankfurt, in part reflecting the evolution of capacity constraints there (see Burghouwt's (2013) discussion of "overflow" hubs).

Finally, whilst our understanding of the factors shaping today's airline network development is incomplete – and often qualitative rather than quantitative – these uncertainties compound as we look into the future. It seems very likely that developments in technology will bring further changes. In particular, the introduction of smaller, lower cost aircraft (such as the Airbus A350 or the Boeing Dreamliner) on long-haul services, coupled with rising demand levels as the world economy starts to recover from the Great Recession, are likely to bring a greater role for point to point services, quite possibly provided from non-hub airports (although these types of aircraft will also support the provision of additional thinner routes from some existing hubs).

Developing and assessing risk management measures

As discussed in the previous section, the main purpose of recognising and quantifying (where possible) risks and uncertainties in future airport demand is to help to develop useful risk management measures. Thus the aim is not simply to tell us how risky and uncertain a proposed investment project might be; rather the aim is to help develop investment strategies which help to control and diversify adverse risks and to reduce their impact upon financial and/or economic returns (and vice versa for upside risks). And in this way, to improve the efficiency and added value of infrastructure investment.

The emerging evidence discussed at the Roundtable suggested productive ways of achieving this, and thus making airport infrastructure investment more robust to the risks and uncertainties in future airport demand. Approaches divide into two broad groups:

- The first involve risk sharing; the aim here is to facilitate the control and/or diversification of risk – in particular, through vertical integration.
- The second approach involves a flexible approach to infrastructure investment – sometimes called (variously) flexible strategic/dynamic strategic/adaptive planning; the aim here is to reduce the (net) costs of unexpected traffic outcomes.

We will consider each of these in turn.

Risk sharing and vertical integration

As the discussion in the previous section illustrated, an important risk to the demand forecasts for some airports – those which face a material degree of competition – is the possibility that key customer airlines may choose to re-locate their business to a competitor airport. This carries the risk of under-utilised – and under-remunerated – infrastructure. And this risk may, in turn, weaken investment incentives (there is of course a different, familiar, set of issues on investment incentives which arise in the case of airports which don't face material competition and are able to exercise market power; here the regulatory framework is a key shaper of investment incentives – ITF/OECD (2014) for a discussion).

In the case of airports which face a material degree of competition, the issues which arise are also found, to different degrees, in many other business settings. The essential problem arise where there is a need for large sunk costs – for example, in physical or human capital or in intangible assets – on one side of the supply chain. This situation raises the risk of ex-post appropriation, or stranding, of the assets. A common business solution is some form of vertical integration, with the aim of assigning particular risks to the parties best able to control the risk, or to diversify it ((for an overview: Kay, 1993). In most cases the form of vertical integration is more subtle than a simple "make-buy" dichotomy and may involve cross ownership (majority or minority), a classic contract or a long term relational contract (Kay, 1993).

In the case of airports, the regulatory reforms of the last several decades have both prompted and facilitated widespread innovation in organisation and ownership (see, for example, Gillen (2011) for a review). And these developing business arrangements quite often involve vertical relationships between airports and airlines (Frohlich, Muller, Nemeth, Niemeier, Njoya and Paskin (2011) for an overview and a discussion of the public policy issues which may arise from vertical links of this kind). In practice, vertical relationships take a range of forms. For example, David Starkie (2012) discusses the role of long term contracts (between airlines and airport), which have been used to manage some of the demand side risks to the development of major infrastructure by providing some control over the risks of asset stranding, at airports in a competitive market setting.

Another example is provided by the various different methods which are sometimes used to, in effect, co-finance airport development (Fu, Homsobat and Oum, 2011). And a further example discussed at the Roundtable is provided by Paris where probabilistic forecasts have been employed since 2003. Optimal points for new capacity, in terms of revenues and costs are determined. This provides the information required for informed negotiation with airlines that request increased capacity. When demand appears insufficient from the airport's point of view airlines can be asked to pay a risk premium if they want the airport to build early. This kind of risk premium can probably be hedged on financial markets. Some other airports are beginning to use this approach.

It is important to recognise that the benefits of vertical links may run wider than just the facilitation of investment in long term infrastructure at airports in a competitive market setting. For example, vertical links may be important to sustaining service quality in the face of unexpected adverse shocks (related to weather or to security threats for example), where trust and co-operation between different parts of the supply chain will often be important to sustaining service quality.

And, of course, it also needs to be recognised that long term vertical relationships carry the risk of anti-competitive restriction, where a vertical link might be used to raise the costs of market entry. There is therefore likely to be a balance of both benefits and costs to at least some vertical links. Competition authorities will need to be alert to this trade off, and the balance of benefits and costs will need to be assessed on a case by case basis. This will not be straightforward. However, the risks of an anti-competitive restraint will generally be greatest in circumstances where an airport has material market power, and this is also where the risks of expropriation/asset stranding are likely to be least strong (and vice versa).Transparency of vertical links will also be important (although not necessarily straightforward to achieve).

It also needs to be recognised that vertical relationships can only improve the control of risks which are endogenous to the aviation business (for example, the risk that an airline will choose to move more of its business to an alternative airport). Vertical integration won't improve the control of exogenous risks (for example, a downturn in the economy), although it might help with the diversification of such risks.

Flexible infrastructure investment

Whilst risk sharing can help to control, or to diversify, the risks associated with airport demand forecasts, a flexible approach to infrastructure investment aims to reduce the net costs of downside risks being realised in practice (or to increase the net benefit, in the case of favourable surprises). This approach has been variously described as adaptive/dynamic strategic/flexible strategic planning (Burghouwt (2007) for a discussion of the detailed differences between these concepts) and is particularly associated with the research of de Neufville and colleagues (see, for example, de Neufville and Odoni (2003).

The basic idea behind this approach is to seek to retain flexibility, either in the scale of the infrastructure – by holding open the possibility of adding to (or subtracting from) the intended capacity – and/or in the timing of the proposed investment. The aim of retaining flexibility in these ways is to help respond to unexpected traffic outcomes and, in this way, to achieve a better fit between the capacity provided and that which turns out to be needed in practice. The approach is sometimes described in a real options framework (Roundtable paper by Ian Kincaid and Nicole Geitebruegge). That is, an infrastructure project is developed in a way which holds open a series of options (essentially to do more or less) which can be taken up in response to changing circumstances (or not, if the central forecasts turn out to be realised).

Of course, flexibility of this type will usually come at a price. That is, holding open an option will usually add to costs. And it will usually, therefore, be less good value to do so in circumstances where the central airport demand forecast turns out to be accurate. The key question is then how much value is added by a flexible solution in circumstances where there are unexpected traffic outcomes; and whether these unexpected outcomes are sufficiently likely to occur in practice, such as to make the flexible option a good investment.

The discussions at the Roundtable suggested that a flexible approach can sometimes (and perhaps often) be worthwhile. The Roundtable paper by Ian Kincaid and Nicole Geitebruegge sets out a range of flexible solutions which have been successfully used in practice (Table 1.1 for a summary).

Table 1.1. **Flexible airport expansion solutions for addressing uncertainty**

Land banking	**Reserving or purchasing land for future development, to allow for the option of expanding the airport as traffic grows.**
Reservation of terminal space	Setting aside space within the terminal for future use. The space can be designed so that it remains productive in the short-term (e.g. using it for temporary retail that can be removed easily).
Trigger points / Thresholds	The next stage of development goes ahead only when predetermined traffic levels are reached.
Modular or incremental development	Building in stages as traffic develops. This avoids committing to a large capacity expansion. At the same time, the airport can respond to strong growth by adding additional modules.
Common Use Facilities/Equipment	Common gates, lounges and terminal space.
Linear terminal design and centralised processing facilities	Allows the greatest flexibility for airport expansion since it is the most easily expandable and allows flexibility in the face of changing traffic mix
Swing gates or spaces	Can be converted from domestic to international traffic (or between types of international traffic) on a day-to-day basis.
Non-load bearing (or glass) walls	As with swing gates, terminal space can easily be converted from one use to another.
Use of cheap, temporary buildings	An example is Amsterdam Schiphol's low-cost carrier pier.
Buses rather than fixed transit systems	The service is easier to expand, contract and redirect.

Source: Kinkaid and Guitebruegge (2014).

Thus while we can't accurately plot the future we can build in flexibility. Real option planning is what follows from an analysis of risk and uncertainty. Flexible design can include the use of "swing gates" and moveable partitions to direct flows of passengers between terminals and planes to different areas of the terminal to relieve crowding – allowing spare capacity in domestic terminal areas to be used by international passengers at peak periods, for example, and vice versa.

Terminals can be constructed in phases rather than as a single large hall and flexible taxiways can be designed to accommodate a wide range of aircraft. "Land banks" can be employed, reserving space for security facilities expected to be required in the future for example, but in the short term using the area for retail services so the space is used for profitable activity. Buildings can be designed to have floors added in the future when expansion is needed. Both are examples of "real option" planning analogous to financial hedging. Whilst initial construction costs are somewhat higher, expansion will be considerably cheaper, reducing construction costs over the long term. Adaptive airport planning is the only response to Black Swans.

Another approach to forecasting that helps respond to risk and uncertainty is to forecast the long term trend and track progress in actual volumes along the trend. Trigger points for expansion are reached as the volume reaches defined points along the trend, but the timing of when these triggers are reached is dependent on outcomes rather than pre-determined by the forecast. This approach is employed at the airports run by the Port Authority of New York (Zupan, 2012).

Thus flexible solutions include, in particular:

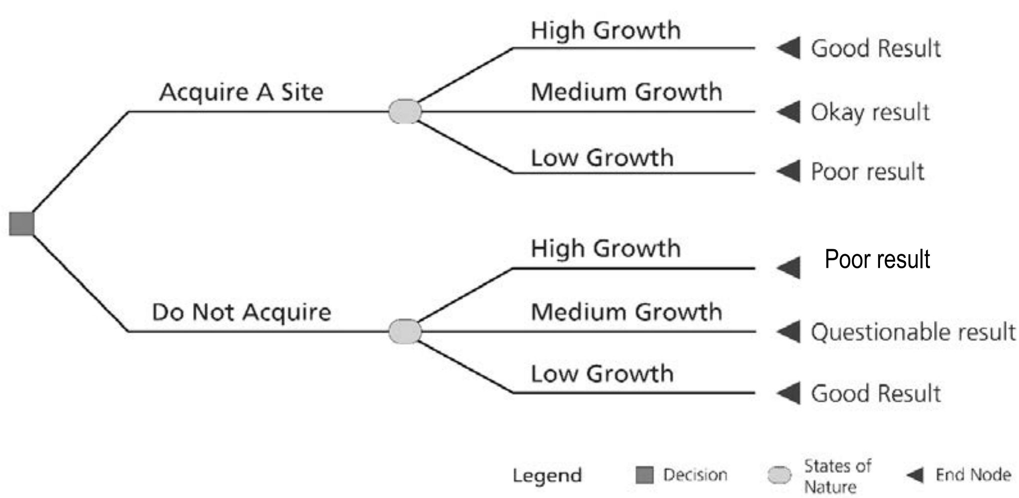
- measures which make provision for future development without, at this stage, making a commitment to expand
- measures which make provision for incremental development as traffic levels develop

- measures which make provision for switching facilities between different types of traffic (e.g. international and domestic)
- measures which make provision for different types of aircraft
- measures which retain flexibility in the start and/or completion dates for a project.

Whilst there is a wide menu of flexible solutions which have been found to work in practice (as summarised in Table 1.1) in order to be successful they will usually need to be tailored to the specific market circumstances (current and prospective) of the airport under consideration. As the Roundtable paper notes "there is no standalone method or tool that can offer the correct set of strategies". The Roundtable paper suggests an approach which builds upon current practice (where ACRP (2012) offers a series of case studies) and then uses expert advice from airport stakeholders and subject experts to suggest solutions which are feasible and relevant to the particular airport under consideration, perhaps using formal elicitation methods to structure this advice.

The evaluation of whether particular flexible solutions are worthwhile can involve qualitative appraisal - based on expert judgement – and this is sometimes sufficient to provide a clear conclusion. For example, the Roundtable paper discusses an assessment of whether or not to reserve land for a (potential) second airport for Sydney. The assessment is summarised in Figure 1.2. In this case, the expert judgement concluded that the option of reserving land would generally be worthwhile across different scenarios for traffic growth.

Figure 1.2. **Decision tree for second Sydney airport**

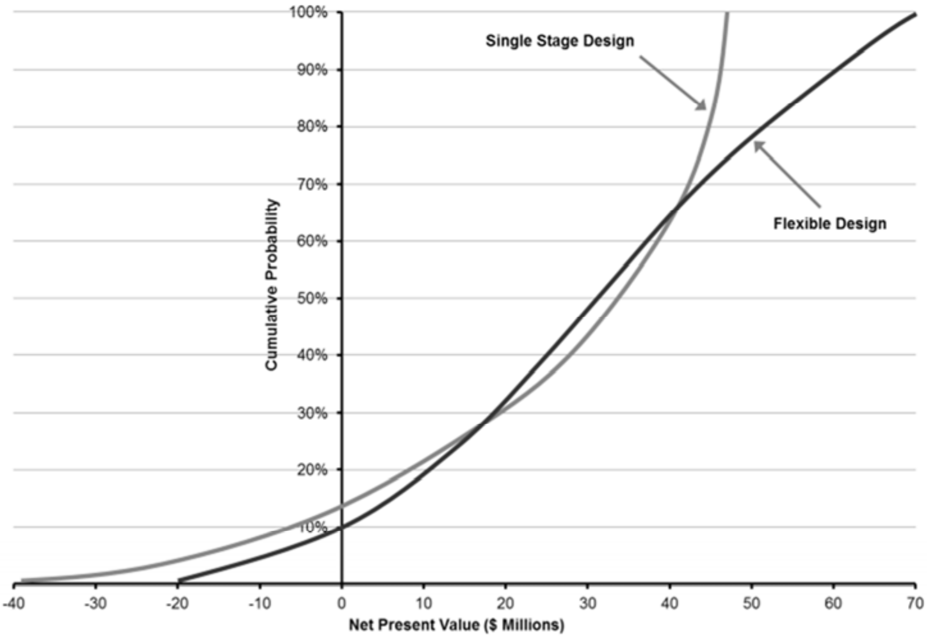


Source: Adapted from ACRP (2012).

In some cases a quantitative appraisal – which aims to measure the expected cost benefit return – will provide a more robust basis for decisions; although of course to do this requires some reasonable estimates of the probabilities of different scenarios for traffic growth (for example, using results from the kinds of Monte Carlo analysis described earlier).

Figure 1.3 provides an illustrative example of this kind of quantitative analysis. In the illustration, the non-flexible solution provides better value on the central traffic forecast. The flexible solution shows better value – in this illustrative case – when traffic levels are either well above or well below the central forecast. The key question is then whether the added value at the lower and higher ends of the forecasting range is worthwhile –in terms of outweighing the lower value which they provide on the central forecast; in the illustration, this is clearly the case.

Figure 1.3. **Example comparing probabilistic net present value**



Source: After Kinkaid and Guitebruegge (2014).

Several case studies of the practical implementation of flexible infrastructure solutions in North America are documented in the ACRP report mentioned earlier (ACRP, 2012), whilst Burghouwt (2007) provides a detailed case study of flexible investment planning at Amsterdam airport. Although many of the examples of flexible infrastructure set out in Table 1.1 work at a relatively micro level – expansion of (a part of) an individual terminal, for example – the principles of flexible strategic planning can equally be usefully applied on a larger scale. For example, de Neufville (1995) considers the development of Amsterdam airport and the possibility of a new offshore airport; he judges this possibility to be an unwise commitment in a flexible planning framework.

More generally still, the UK Airports Commission are following an approach which might be characterised as an application of flexible strategic planning at the level of the whole London airports market. As a rule, flexible investment implies only building one runway at a time, building a second only when absolutely necessary. London's airports have maximised their return on investment in this way, by design or accident, and Gatwick carries 35 million passengers a year with just one runway. Airport building leads to higher charges, unless government decides to fund largely through general taxation. In other circumstances over-building will increase charges and that will depress demand and encourage passengers to use alternative airports. Athens' new airport provides a clear example of this effect.

In the UK, the Airports Commission has recommended that just one new runway be built to provide for growth in the London area, despite both Heathrow and Gatwick operating close to capacity, in order to keep prices competitive and contain the risks of over-investment. Conclusions on where to build have yet to be reached. Potential step-changes in airline behaviour are a key uncertainty. This includes the possibility of airlines relocating between airports and whether Gatwick could host a second hub operation in the London area. Expansion of Gatwick may represent increased flexibility. London benefited from its constellation of airports that evolved by accident more than design, as this proved very suitable for the entry of low cost carriers. Expansion of Heathrow would permit expansion of constrained hub traffic.

Note

1. The worldwide aviation regime is a mosaic of liberalized air service agreements, open skies treaties, regulated and deregulated national/regional aviation markets and traditional Bermuda-type air service agreements. For example, until EU-US Open Skies British Airways served Dallas, hub of its partner American Airlines, from Gatwick instead of Heathrow due to bilateral restrictions. For EU carriers, as long as the Community Carrier Clause is not accepted in all relevant bilateral agreements with non-EU states and the criterion of principle place of business has not been accepted in global air transport policy, carriers must rely on such traditional nationality clauses. These clauses limit the extent to which a multi-national airline can shift non-EU services between their European hubs. Finally, access to many markets is only possible by making use of hubs of alliance partners. For example, European network carriers can only access most cities in China by means of an alliance with Chinese carriers and creating connections through their hubs (Burghouwt, 2014).

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