THE TREATMENT OF UNCERTAINTY IN AIRPORT STRATEGIC PLANNING: 
THE CASE OF SCHIPHOL AIRPORT’S LONG-TERM VISION

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Abstract

Airport Strategic Planning (ASP) focuses on the development of plans for the medium- and long-term development of an airport. In general, airports do not have a good track record for making good long-term decisions, primarily because they fail to take uncertainties about the future into account in a proper way. With the recent dramatic changes occurring in the context in which an airport operates (e.g., low cost carriers, new types of aircraft, and the liberalization and privatization of airlines and airports), the uncertainties airports face are bound to increase. Hence, there is an even greater need for improvements in the way ASP takes uncertainty about future developments into account. This paper reviews the treatment of uncertainty in the current debate about the future of Amsterdam Airport Schiphol. We examine documents related to the debate to identify key uncertainties and how they are being treated. We critically review these uncertainties and suggest uncertainties that are missing but might be of relevance. Finally, we review the current treatment of the different uncertainties and suggest alternative treatments in light of recent theoretical developments in the Airport Strategic Planning literature. More specifically, we suggest how ideas from Adaptive Policymaking, Dynamic Strategic Planning, and Flexible Strategic Planning, such as real options, hedging, and monitoring, could help in improving the performance of plans produced by the policy debate.

Keywords: Airport Master Planning, Uncertainty, Dynamic Strategic Planning, Adaptive Policymaking, Flexible Strategic Planning
1 Introduction

The aviation industry operates in a fast changing environment. At the end of the 1970’s, the air transport industry was liberalized and privatized in the U.S.A. Europe followed in the 1990’s. As a result of this privatization and liberalization, the air transport industry underwent unprecedented changes, exemplified by the rise of airline alliances and low cost carriers. It is likely that the aviation industry will become even more dynamic in the coming years, for example because of the recently signed U.S.A.-Europe Open Skies treaty. This poses a major challenge for airports. They have to make investment decisions that will shape the future of the airport for many years to come. However, they do not know what the future will be like. The current approach for the long-term development of an airport is Airport Master Planning. However, this approach dates back to when the air transport industry was heavily regulated and as a result more predictable. In light of the dynamics and the many uncertainties airports face, an alternative approach is needed.

In this paper, we explore in more depth how uncertainty is currently treated in airport strategic planning. In the next section, we take a more detailed look at Airport Master Planning (AMP). In Section 3, we introduce a conceptual framework for the classification of uncertainties. This framework is applied to the current policy debate about the long-term development of Schiphol in Section 4, where we also discuss several alternative planning approaches that are better equipped to deal with the uncertainties now faced by airports. Section 5 contains our conclusions.
2 The Problem of Uncertainty in Airport Strategic Planning

Airport strategic planning (ASP) focuses on the development of plans for the medium and long-term development of an airport. Strategic planning is defined as ‘the managerial activities that produce fundamental decisions and actions that shape and guide what the organization is, what it does, and why it does it’ (Bryson, 1995). Strategic planning can be done in many different ways. In airports, the dominant approach is AMP. AMP is a formalized, structured planning process that results in a Master Plan that ‘presents the planner’s conception of the ultimate development of a specific airport’ (ICAO, 1987, pp. 1-2). As such, the focus in AMP is on the developments of plans and not on the decisionmaking process about the plans. Admittedly, this decisionmaking process is interwoven with the AMP process, but for analysis purposes we focus here on the AMP process. In the United States, the FAA has set up strict guidelines for an AMP study (FAA, 2005). Internationally, reference manuals of IATA and books about airport planning by leading scholars heavily influence AMP practices (e.g. de Neufville & Odoni, 2003; IATA, 2004; ICAO, 1987).

The goal of a Master Plan is to provide a blueprint that will determine future airport developments (Burghouwt & Huys, 2003; Dempsey, Goetz, & Szyliowicz, 1997). As such it describes the strategy of an airport operator for the coming years, without specifying operational concepts or management issues. The time horizon covered in a Master Plan can vary, depending on the situation of the airport for which the Master Plan is being developed. A short-term Master Plan has a time horizon of roughly 5 years, a mid-term Master Plan has a time horizon of 6 to 10 years, and a long-term Master Plan
has a time horizon of 20 years (FAA, 2005). AMP follows a strict linear process. The most commonly used guidelines are fundamentally the same, although they differ in detail (de Neufville & Odoni, 2003). The key steps in an AMP process are:

- Analyze existing conditions
- Make an aviation demand forecast
- Determine facility requirements needed to accommodate this forecasted demand
- Develop and evaluate several alternatives to meet these facility requirements
- Develop the best alternative into a detailed Master Plan

A crucial challenge in ASP is how to deal with uncertainty about the future, since decisions made today will shape and influence the airport performance for many years to come. For example, the decision to build a new runway on a specific location will likely influence airport performance more than fifty years from now. A thorough assessment of the many potential developments that can influence the future in which the airport will operate is therefore necessary if one wants to plan effectively. In AMP, however, only demand uncertainties are considered through aviation forecasting. Often, only a single demand forecast is created, and a Master Plan is designed based on this single forecast. As a result, AMP has proven to be ineffective (de Neufville & Odoni, 2003; Dempsey, Goetz, & Szyliowicz, 1997; Kwakkel, Walker, & Marchau, 2007; Nelkin, 1974, 1975; Szyliowicz & Goetz, 1995).

3 Uncertainty Analysis

A general definition of uncertainty is ‘any departure from the unachievable ideal of complete determinism’ (Walker et al., 2003). Uncertainty is not simply a lack of knowledge, since an increase in knowledge might lead to an increase of knowledge about
things we do not know and thus increase uncertainty. Walker et al. (2003) identify three dimensions of uncertainty, upon which they develop a conceptual framework for the systematic treatment of uncertainty in model based decision support.

With model based decision support, Walker et al. (2003) refer to the role of models in policymaking processes. Policymaking processes involve policymakers, stakeholders, and researchers giving policy advice. Often, the researchers are applied scientists, who base their policy advice on an analysis of the expected outcomes of alternative policies. The expected outcomes are usually estimated through models. The term model should be understood in a broad sense, and covers models ranging from conceptual diagrams to detailed computer models using complex mathematics. Following Walker et al. (2003), we call this approach to policy advice “model based decision support”.

AMP also relies heavily on models, and therefore it can be perceived as an example of model based decision support. Both aviation forecasting and the evaluation of alternatives in terms of airside capacity and delay, costs and benefits, noise, and emissions rely heavily on models (de Neufville & Odoni, 2003; Wijnen, Walker, & Kwakkel, 2008). Since ASP is depended on model based decision support, the framework of Walker et al. (2003) is considered to be suited for the analysis of the uncertainties in ASP.

### 3.1 The Location of Uncertainty

The first dimension in the conceptual framework is the location of uncertainty. This dimension focuses on where the uncertainty is located in the system model. A system model is an integral description of the policy field for which the analysis is being
conducted. A system model does not necessarily have to be a computer model, and it can be composed of multiple models that together constitute a integral description of the policy field. For example, in ASP, the system model would contain a description of the airport and its surrounding area (i.e. a data model), and models for the calculation of airport performance metrics, such as capacity, delay, noise, and emissions. These models are usually implemented in third-party tools; examples are the Integrated Noise Model (INM) and the Emission and Dispersion Modeling System (EDMS).

Figure 1: System model

Figure 1 can be used to specify the different possible locations of uncertainty with respect to the system model. Uncertainty about inputs is associated with the available data and its use in calibrating the model. The distinction between controllable and uncontrollable inputs is useful in this case, since some of the input parameters to the system model can be controlled by the decisionmaker through policies and others not. Examples of controllable input parameters are the parameters that describe the terminal or the runway
system, both the terminal and the runway system can be changed by the airport operator. Uncontrollable inputs are external driving forces that produce changes in the system. In case of AMP, technological developments (e.g. A380, B787, new ATM technology, new engine technology) and demand are examples of uncontrollable inputs.

Uncertainty located within the system model can be divided into model structure uncertainty, parameter uncertainty, and model technical uncertainty. Model structure uncertainty is uncertainty about the structure of the model, due to uncertainty about how to model what happens inside the system and how the system operations produce the outcomes of interest. For example: the runway system is typically modeled as a queuing system, but in practice there are situations where it does not behave as predicted by queuing theory (e.g. Janic, 2003), parameter uncertainty is uncertainty about the values of the model parameters given the model structure. Model technical uncertainty arises out of the computer implementation of the model, which can produce errors resulting from the software and hardware being used. For example: the implementation of the calculation methodology of noise exposure in Kosten units did not take into account individual noise levels below 65 dBA (To70, 2007).

Uncertainties about the outcomes, or model outcome uncertainties, are the accumulated effects of all the other uncertainties. The uncertainties located at other places in the model complex propagate through the model and result in uncertainty in the model outcomes. This location of uncertainty is sometimes also referred to as the prediction error. This label, however, implies that the results from the model can be compared to real word
outcomes. In case of policy advice however, models are mostly used for estimating future outcomes, rendering such a formal model validation impossible. Still, in the aviation industry such a formal validation is still attempted. For example, the latest FAA forecast contains an appendix about the forecast accuracy (FAA, 2008). By using historical data, it is attempted to show that the forecast is likely to be roughly right. However, there is no structure in the error of the prediction, nor can one use this ex post analysis to claim that a new forecast will have the same error.

A final category of uncertainty is the uncertainty associated with the choice of the system boundary. This uncertainty, also known as context uncertainty, focuses on the choices that have been made when developing the model. When developing the system model, decisions are made about what parts of reality to include in the model. Since these system boundary choices influence the results of the model and thus influence the advice that is based on the model, context uncertainty is an important source of uncertainty. For example, in the noise calculations for Amsterdam Airport Schiphol (AAS), ground noise from landing (reverse thrust) and taxiing aircraft was not deemed relevant. As a result of complaints from several municipalities, the problem of ground noise was acknowledged (Commissie_MER, 2007), and several alternatives were proposed to mitigate this problem (Dutch_Cabinet, 2006).

### 3.2 The Level of Uncertainty

The second dimension is the level or extent of uncertainty. Knowledge about any given phenomenon can range from complete deterministic understanding to complete ignorance. As can be seen in Figure 2, the level of uncertainty progresses from
determinism, through statistical uncertainty, scenario uncertainty, and recognized ignorance, to total ignorance.

Figure 2: Levels of uncertainty

Uncertainty that can be expressed adequately in statistical terms is called statistical uncertainty. This is the main type of uncertainty that is considered in the natural sciences. Uncertainty that cannot be expressed in probabilistic terms, but plausible values or plausible relationships are known, is called scenario uncertainty. Its name is derived from the scenario approach, which is a family of methods for the treatment of uncertainty in policymaking. Uncertainty is considered to be recognized ignorance if the fundamental relationships, mechanisms, and values of a phenomenon are not known or cannot be agreed on by the different stakeholders. The final category of uncertainty is the unknown unknown or total ignorance.

3.3 The Nature of Uncertainty

The third dimension is the nature of uncertainty. This dimension focuses on the character of the uncertainty. Is the uncertainty inherent in the knowledge of the phenomenon
(epistemic uncertainty), or is the uncertainty due to natural variability in the phenomenon (variability uncertainty)? Admittedly, it is not always possible to clearly distinguish between these two categories for a given uncertainty. Still, analyzing the nature of uncertainty can help in choosing the appropriate action for the treatment of uncertainty. If for example the uncertainty is epistemic, further research would be a good strategy.

4 The Case of Amsterdam Airport Schiphol

In Section 2, we described in some detail the problem uncertainty poses for ASP. In Section 3, we introduced a conceptual framework for the analysis of uncertainty. Here, we will use this framework to study the problem of uncertainty in ASP in more detail for the specific case of Amsterdam Airport Schiphol.

4.1 Background of the case study

Fuelled by privatization and liberalization of the aviation industry, aviation demand in Europe has undergone unprecedented growth since the early 1990’s. Schiphol benefited from this growth and evolved into a major hub in Europe. Since 1990, Schiphol invested in expanding its runway system and its terminal. Parallel to the increasing number of passengers and flights handled at Schiphol, negative external effects also increased, resulting in national regulations concerning noise, emissions, and third party risk. Nowadays, Schiphol’s position as a hub within Europe is under pressure. Schiphol was surpassed by Madrid in 2006 and now ranks as Europe’s fifth airport in terms of air transport movements. The merger of Air France and KLM has resulted in the threat that KLM, the hub carrier of Schiphol and responsible for 52% of the scheduled movements, might move a significant portion of its operations to Charles de Gaulle airport. The other
major airports in Europe are planning on expanding their capacities or developing into dual airport systems. In addition, resistance from key stakeholders to the further growth of Schiphol is ever increasing. Together this results in many uncertainties, making the long-term planning of Schiphol both urgent and problematic.

In its current long-term planning, the main goals of the Schiphol Group are to create room for the further development of the network of KLM and its Skyteam partners, and to minimize and where possible reduce the negative effects of aviation in the region (Schiphol_Group & LVNL, 2007). The Schiphol Group is primarily interested in medium- to long-term developments until 2020. Policy options that are being considered by the Schiphol Group include the further development of the current operational plan, a new operational concept, moving charter operations out of Schiphol, and a proposal by inhabitants of the region (Schiphol_Group & LVNL, 2007). The current operational plan is based on a hub-and-spoke network and a Preferential Runway Advisory System (PRAS), similar to Boston’s Logan Airport, for the usage of the runway system in order to minimize noise impact. In order to handle the arrival and departure peaks, a 2+2 runway configuration will be required. The new operational concept is based on the continuous usage of four runways, combined with a concentration of arrival and departure traffic flows. The proposal of the inhabitants is based on a cap on the maximum number of operations, combined with a 2+1 runway system. An additional runway might be used under strict conditions and only for a short period during the day.
Currently, there is an ongoing debate among the Schiphol Group, different branches of the national government, the province of North Holland, Air Traffic Control the Netherlands, and the municipalities surrounding Schiphol, about the future of Schiphol. Within this context, a problem analysis has been performed by a department of the Ministry of Transport. We see this problem analysis as the starting point of the current policy debate.

### 4.2 Uncertainties in documents

Figure 3 shows a system diagram for Schiphol Airport. A system diagram is a simplified depiction of the main system elements, the external forces acting on the system, the policy options of the decision maker, and the outcomes of the system that are of interest to the decisionmakers and stakeholders. On the left, the main categories of external forces are shown. These are forces that the airport operator cannot control but that have a significant impact on the operations and performance of the airport. The system is composed of the runway system, the terminal, and the ATM system (simplified for the purpose of this paper). The outcomes of interest to the airport operator and other stakeholders include capacity and delay of the runway system and the terminal, noise, emissions, third party risk, and the airport’s financial performance. The policies include those mentioned in Section 4.1. The diagram will be used in this section to specify the location of the major uncertainties.
In order to identify the different uncertainties Schiphol is facing for its long-term development, we began by reviewing the relevant policy documents that are being used within the current policy debate. We classified something as an uncertainty if it is specifically perceived as such by any of the stakeholders or if there is disagreement about it expressed in the documents. In this respect we follow the methodology used by Krayer von Krauss (2005). Krayer von Krauss (2005) is one of the co-authors of the uncertainty typology introduced in Section 3, and his methodology is based on this typology. The only difference with his methodology is that he complemented the literature review with interviews and other additional verification steps and we did not. The table below summarizes our results. It contains a label for the uncertainty, a short explanation, and references to where the uncertainty can be found in the policy documents.

**Table 1: Overview of Uncertainties**

<table>
<thead>
<tr>
<th>Uncertainty</th>
<th>Short Explanation</th>
<th>Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aviation demand</td>
<td>Over the last few years, aviation demand has fluctuated tremendously. Events such as epidemics and terrorist attacks have resulted in short-term</td>
<td>(CPB, KiM, NMP, &amp; RP, 2007, p. 9; Ministry of Transport, 2007,</td>
</tr>
<tr>
<td><strong>Fleet mix</strong></td>
<td>As a result of privatization and liberalization, airline networks have become more dynamic. This results in increasing uncertainty about the types of aircraft that will visit the airport and their distribution over the day and year.</td>
<td></td>
</tr>
<tr>
<td><strong>Aviation technology</strong></td>
<td>The aviation industry has always been focused on improving performance by technological advances. In the coming years, new aircraft will enter service and the existing fleet will undergo improvements. How will aviation technology develop in the coming years?</td>
<td></td>
</tr>
<tr>
<td><strong>ATM technology</strong></td>
<td>Air traffic management technology has seen significant technological advancements throughout the history of aviation. New ATM technology can change the way in which aircraft take off and land and affect separation standards. Together, such changes can significantly change the capacity and external effects of Schiphol. How will ATM technology develop in the future?</td>
<td></td>
</tr>
<tr>
<td><strong>Evaluation of outcomes</strong></td>
<td>Different stakeholders value the outcomes differently. In addition, the valuation of outcomes is likely to change over time. For example, until the terrorist attacks, security at the airport was of limited concern. Now, it is a key issue. In addition, in the reports it is assumed that quality of living will become more important in the coming years. Noise will then be experienced as even more of a hindrance.</td>
<td></td>
</tr>
<tr>
<td><strong>Demography</strong></td>
<td>The demography of the Netherlands will change over time. Where will people live and what will be the composition of the population in age and ethnicity in the future?</td>
<td></td>
</tr>
<tr>
<td><strong>Land use developments</strong></td>
<td>Schiphol is located in a densely populated area where land is scarce. Already, there is a lack of housing for skilled labor, negatively affecting the attractiveness of the region as a location for international companies. How will the land use in the region evolve, also considering the potential evolution of the region?</td>
<td></td>
</tr>
<tr>
<td><strong>Landside accessibility</strong></td>
<td>A major source of demand for Schiphol comes from its catchment area. In making a choice between alternative airports, customers more and more take into account not only the ticket price but also how accessible the airport is. Landside accessibility includes the time it takes to get to the airport, the costs of reaching the airport, and the efficiency of</td>
<td></td>
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</tbody>
</table>
check in (e.g. security checks) at the airport. How will the landside accessibility of Schiphol evolve in the coming years?

Weather patterns
The runway system of Schiphol is quite sensitive to cross wind conditions. The main problem is the strong westerly wind. Due to climate change, it is imaginable that such wind conditions will become more frequent. How plausible are such changes to the weather pattern and how will they affect Schiphol’s performance?

Rules & Regulations
The aviation industry in general and airports in particular are subjected to numerous rules and regulations that determine how the industry functions. Due to, for example, changes in political power, new rules and regulations can come into force that will significantly alter how the airport is to be operated. More specifically, how will new regulations, such as an emission trading scheme or taxation on fuel, affect Schiphol?

Modal Choice
There is a push in Europe for developing an integrated high speed rail system that should compete with short haul aviation. How will this evolve over time and what modal choices will passengers make?

<table>
<thead>
<tr>
<th>Uncertainty</th>
<th>Short Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Absolute levels of impacts</td>
<td>The assessment of the impacts of operating an airport relies on models. In general, these models change over time with the advancing understanding generated by scientists. For example, new knowledge is becoming available about the adverse health effects of exposure to aircraft noise. How will new scientific insights affect our understanding of the impacts?</td>
</tr>
<tr>
<td>Rules for calculation of impacts</td>
<td>The assessment of the impacts of operating an airport relies on models. In the case of Schiphol, there are calculation rules that prescribe how noise contours should be calculated. These rules until now have been resilient to changes in light of the latest scientific insights. Will this remain the same?</td>
</tr>
<tr>
<td>System operations</td>
<td>Overall, the operations of an airport are well understood. Still, there remain minor differences between the models and rules, and the actual</td>
</tr>
</tbody>
</table>
Most of the uncertainties that are of relevance for the long-term development of Schiphol are explicitly acknowledged in the reviewed documents. The different policy documents have special section dedicated to discussing the uncertainties and how they should be treated. The Schiphol Group proposes to explicitly address the major uncertainties and to assess their impact on the outcomes of interest. Their suggested approach is to use the available information and experience, combined with different plausible future developments, to estimate a range of plausible impacts. The identification of plausible future developments is to be based on a sensitivity analysis of key parameters. In contrast, the planning bureaus suggest using a scenario approach for the key forces that are outside the control of the decisionmakers. To our knowledge, a final decision on the approach has not been made yet.

Regardless of the decisions that will be made in the policy debate about the treatment of the many uncertainties, what should be done first is to assess the different uncertainties and characterize them. In light of the characterization of the uncertainties, an appropriate treatment should be agreed upon by the different stakeholders and decisionmakers. Below, in Table 3, we give our characterization of each of the uncertainties, using the conceptual framework introduced in section 3, and the treatment that is proposed in the policy documents. When looking at the level of the uncertainty, the time horizon is an issue. Schiphol looks at a time horizon of roughly 15 years, which is what we have used

<table>
<thead>
<tr>
<th>Implementation uncertainty</th>
<th>For any policy option that Schiphol would like to implement, it remains uncertain to what extent Schiphol is able to do this and what support it needs from other stakeholders</th>
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in our characterization. If instead a longer horizon, up to 2040 or even beyond would be used, as is suggested by the planning bureaus, the level of uncertainty would be greater. Most uncertainties would then be classified as recognized ignorance or even total ignorance.

Table 3: Characterization of the Uncertainties and Their Treatment

<table>
<thead>
<tr>
<th>Uncertainty</th>
<th>Characterization</th>
<th>Level</th>
<th>Nature</th>
<th>Proposed Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aviation Demand</td>
<td>Uncontrollable input</td>
<td>Scenario</td>
<td>Epistemic</td>
<td>Forecasting and scenarios</td>
</tr>
<tr>
<td>Fleet mix</td>
<td>Uncontrollable input</td>
<td>Scenario</td>
<td>Epistemic</td>
<td>Forecasting and scenarios</td>
</tr>
<tr>
<td>Aviation Technology</td>
<td>Uncontrollable input</td>
<td>Scenario</td>
<td>Epistemic</td>
<td>Specific assumptions, the planning bureaus criticize this and suggest scenarios</td>
</tr>
<tr>
<td>ATM Technology</td>
<td>Uncontrollable input</td>
<td>Scenario</td>
<td>Epistemic</td>
<td>Specific assumptions, the planning bureaus criticize this and suggest scenarios</td>
</tr>
<tr>
<td>Evaluation of Outcomes</td>
<td>Outcomes and Context</td>
<td>Recognized ignorance</td>
<td>Epistemic</td>
<td>Specific Assumptions</td>
</tr>
<tr>
<td>Demography</td>
<td>Uncontrollable input</td>
<td>Statistical uncertainty</td>
<td>Epistemic</td>
<td>Specific assumptions, the planning bureaus criticize this and suggest scenarios</td>
</tr>
<tr>
<td>Land Use Developments</td>
<td>Uncontrollable input</td>
<td>Scenario</td>
<td>Epistemic</td>
<td>Mentioned as an issue, but no discussion of treatment</td>
</tr>
<tr>
<td>Land Side Accessibility</td>
<td>Uncontrollable input</td>
<td>Scenario</td>
<td>Epistemic</td>
<td>Mentioned as an issue, but no discussion of treatment</td>
</tr>
<tr>
<td>Weather patterns</td>
<td>Uncontrollable input</td>
<td>Recognized ignorance</td>
<td>Epistemic</td>
<td>Mentioned as an issue, but no discussion of treatment</td>
</tr>
<tr>
<td>Rules &amp; Regulations</td>
<td>Uncontrollable input</td>
<td>Recognized ignorance / total ignorance</td>
<td>Epistemic</td>
<td>Ignored</td>
</tr>
<tr>
<td>Modal Choice</td>
<td>Uncontrollable input</td>
<td>Recognized ignorance</td>
<td>Epistemic</td>
<td>Mentioned as an issue, but no discussion of treatment</td>
</tr>
<tr>
<td>Absolute Levels of Impacts</td>
<td>Outcomes</td>
<td>Recognized ignorance</td>
<td>Epistemic</td>
<td>Ignored</td>
</tr>
<tr>
<td>Rules for calculation of Impacts</td>
<td>Uncontrollable input</td>
<td>Recognized ignorance</td>
<td>Epistemic</td>
<td>Ignored</td>
</tr>
<tr>
<td>System Operations</td>
<td>System</td>
<td>Statistical uncertainty</td>
<td>Natural Variability</td>
<td>Addressed by drawing upon past performance. For example, the actual flight tracks instead of the prescribed tracks are used for noise calculations</td>
</tr>
<tr>
<td>Implementation uncertainty</td>
<td>Controllable input</td>
<td>Recognized ignorance</td>
<td>Epistemic</td>
<td>Some high level discussions about the need for cooperation, but otherwise</td>
</tr>
</tbody>
</table>
From the above characterization of the uncertainties and the proposed treatment, we draw two conclusions. First, and most importantly, of the uncertainties that are acknowledged, many appear to be mistreated. Looking at Table 2, there seems to be a mismatch between the treatment and the character of the uncertainty. For example, many uncertainties are of a scenario or recognized uncertainty level. For these, the proposed treatment is to make specific assumptions. The planning bureaus, in their publication (CPB, KiM, NMP, & RP, 2007), rightly criticize this approach, referencing a document that is based on the same conceptual framework for the characterization of uncertainty as used in this paper (i.e. Mathuijsen, Petersen, Besseling, Rahman, & Don, 2007).

Second, several key uncertainties are ignored. For example, the potential of new scientific insights into the impact of aviation, or changes in the rules for calculating outcomes, are ignored. By ignoring these, it becomes plausible that if such changes do occur, the entire plan becomes obsolete. For example, if the rules for calculating noise would change to include the latest scientific insights, the noise contours would become larger. More houses would then be located within the different contours than are allowed under the current rules. Any expansion plan is then in danger of being stopped, because it would not comply with the regulatory context. How then, should the complete set of uncertainties be dealt with?
4.3 How to deal with the complete set of uncertainties

In light of the many uncertainties and their severity (i.e. many are at the level of recognized ignorance or total ignorance), how should Schiphol develop its long-term plan? The traditional way to treat uncertainty in ASP is through AMP. Based upon a single forecast of future traffic demand, a blueprint for the future of the airport is designed. Since this approach considers only demand uncertainties, most uncertainties are ignored, and the forecast is almost always wrong. As a result, AMP results in serious negative consequences for the long-term development of an airport, including an inability to implement the plan, severe capacity constraints due to unanticipated regulations, an inability to meet the actual demand, and unnecessary investments in airside and landside facilities. In the current policy debate about the long-term development of Schiphol, the proposed treatment for many uncertainties is very similar to how uncertainty is treated in AMP in general, as can be deduced from the last column in Table 2, where many uncertainties are treated through specific assumptions or simply ignored. For example, aviation demand and fleet mix are predicted using forecasting for three economic scenarios and the future developments of landside access and land use are ignored.

A first alternative would be to develop a plan based on a scenario approach. Multiple plausible future developments outside the control of the problem owner would be identified, and based upon these, several plausible scenarios could be developed. A plan could then be designed to be robust across these scenarios. In the case of Schiphol, this approach is advocated by the planning bureaus (CPB, KiM, NMP, & RP, 2007). Still, this approach is suitable only if the level of the uncertainty is such that different plausible
developments can be identified (i.e. scenario level uncertainty). However, many of the uncertainties Schiphol faces are more severe and are classified as recognized ignorance or even as complete ignorance. For these uncertainties it is very difficult if not impossible to identify plausible developments. To include highly uncertain developments in scenarios is very difficult. In addition, infrastructure investments have a long lifetime. This is reflected by the planning bureau’s advice to look at a time horizon of 35 years. However, at such a time horizon, the severity of the uncertainty would increase even more, implying that it would become even more difficult to use a scenario approach.

A second and relatively new alternative would be to use an adaptive or flexible approach. Instead of predicting what will happen, as is done in AMP, or identifying several plausible developments, as in the scenario approach, the central idea of the adaptive approach is to let parts of the uncertainty resolve themselves over time. Based on how events unfold, necessary actions are taken. Due to this, an adaptive approach would be able to deal with recognized ignorance by monitoring the relevant uncertainties, and would even be able to cope with the effects of total ignorance by being prepared to change policies when the unexpected occurs. Illustrations of this adaptive or flexible idea are de Neufville’s Dynamic Strategic Planning (de Neufville, 1991, 2000; de Neufville, 2003, 2004; Karlsson, 2003), Adaptive Policymaking (Kwakkel, Walker, & Marchau, 2007; Walker, Rahman, & Cave, 2001), and Flexible Strategic Planning (Burghouwt, 2007). Note that these three adaptive or flexible approaches are still conceptual and have not been developed into detailed planning approaches yet, nor have they actually been applied in practice. In addition, the three approaches are compatible, and there is no
reason why they cannot be combined into a single encompassing adaptive planning approach. But, we discuss them separately below.

Dynamic Strategic Planning (DSP) offers a new approach to AMP, although it is still based on traditional systems analysis, which is also at the heart of AMP (de Neufville & Odoni, 2003). DSP is an approach for making plans, particularly for infrastructure developments, that can be easily adjusted over time to the actual situation and conditions. In this way, bad situations can be avoided and opportunities can be seized. The resulting dynamic strategic plan defines a flexible development over several stages; it commits only to a first stage, and then proposes different developments in the second and subsequent stages. DSP recognizes that the future can not be anticipated accurately and hence that all forecasts will be wrong. Therefore, a plan should build in flexibility to deal effectively with a range of futures. In DSP, this flexibility is created through real options (de Neufville, 2000) An option is a right, but not an obligation, to take an action for a certain cost at some time in the future, usually for a predetermined price and a given period (de Neufville, 2003). A simple example of a real option is to make a land use reservation.

Adaptive Policymaking (APM) is proposed as a generic approach for the treatment of all types of uncertainty. It recognizes that in a rapidly changing world, fixed static policies are likely to fail. Over time, however, we learn, reducing the uncertainty, in light of which we have to act. To plan effectively in such a changing world, therefore, we should plan adaptively and allow for this learning (Walker, 2000; Walker et al., 2001). The APM
process can be split into two phases: a thinking phase, during which the adaptive policy is developed, and an implementation phase, during which the policy is implemented, its performance monitored, and the policy adapted if necessary. During the thinking phase, a basic policy is designed and subsequently analyzed for vulnerabilities. The identified vulnerabilities are screened on the level of uncertainty. The relatively certain vulnerabilities are taken into account in the basic policy by including mitigating actions that should be taken when starting the implementation of the basic policy. For some of the uncertain vulnerabilities, hedging actions are implemented to make the basic policy more robust. In addition, a monitoring system is created for other uncertain vulnerabilities and actions are prepared to be taken for when the monitoring reveals that specific uncertainties manifest themselves. During the implementation phase, events unfold, the signposts are monitored and defensive or corrective actions are taken if necessary. The implemented policy remains active as long as the signposts signify that the policy is on course to achieve its intended outcomes. Otherwise, a reassessment is of the policy is necessary.

Flexible Strategic Planning (FSP) is suggested as an alternative to traditional AMP. To our knowledge, the only discussion of FSP is by Burghouwt (2007). In light of the inability to forecast future traffic accurately as a result of the increasing volatility of aviation demand and airline network development, a more flexible and pro-active planning style is necessary. The approach draws heavily on DSP, but adds to this the notion of pro-active planning. Airports should try and shape the future through its own actions. In order to realize a flexible strategic plan for an airport, FSP relies on real
options, scenario style robustness, backcasting, contingency planning, monitoring, experimentation, and diversification. The discussion in Burghouwt (2007), however, is very brief. Exactly how FSP should work and how it could be applied in practice remain open issues. Burghouwt (2007) explicitly acknowledges this and adds that there is little empirical evidence to support a flexible adaptive approach; the creation of flexibility and adaptability is often difficult in light of the stakeholders affected by the airport, and more sophisticated tools are needed to support airport planners using the flexible approach than those needed for traditional AMP.

Adaptive or flexible approaches to airport strategic planning appear to be better equipped to deal with the many uncertainties airports face. However, we do agree with Burghouwt (2007) that significant work is required before the existing ideas about adaptive or flexible planning approaches can be used in practice. Furthermore, there are now at least three different ideas for an adaptive flexible approach for ASP – APM, DSP, FSP - , all of which are still conceptual and sketchy. It might be possible to combine the ideas from all three into a single approach for airport strategic planning that will aim at developing flexible and adaptive plans. In light of this, the next research challenge would be to explore how ideas from DSP, APM, FSP, and perhaps other flexible or adaptive strategic planning approaches, can be combined into a single coherent adaptive approach for ASP. After that, a method for testing and comparing the new approach’s performance with traditional Master Planning needs to be found in order to provide empirical evidence for the efficacy of this new adaptive approach. In parallel, work is required on developing tools that will support airport planners in their decisionmaking tasks. Work currently
being carried out in the field of Decision Support Systems might be adapted to serve this purpose (e.g. Stamatopoulos, Zografos, & Odoni, 2004; Wijnen, Walker, & Kwakkel, 2008; Zografos & Madas, 2007).

5 Conclusions

The aviation industry operates in a rapidly changing environment. In light of the recent U.S.A-Europe Open Skies treaty, it is likely that the aviation industry will become even more dynamic. This poses a major problem for airports, for they have to make investment decisions without knowing what the future will be like. Airport Master Planning, the current approach for the long-term strategic planning, dates back to days when the aviation industry was heavily regulated. Hence, it is ill equipped to deal with the many and diverse uncertainties airport face, and an alternative approach is needed.

The case study of the current debate about the future of Schiphol illustrates the many diverse and severe uncertainties airports face. However, the Schiphol Group proposes to treat these uncertainties either through sensitivity analysis, or by making specific assumptions. The planning bureaus advocate a scenario approach to allow for a more thorough investigation of the uncertainties. Still, this approach remains unsatisfactory if one wants to take into account the long lifetime of infrastructure investments.

We discussed three alternatives to traditional airport strategic planning that move beyond the scenario approach. The three are similar, in the sense that they propose to make long-term plans more flexible and adaptable. In this way, the airport can let part of the uncertainty resolve itself over time, and take actions only when there is an indication that
they are needed. All three approaches are still conceptual, and it might be possible to integrate them into a single adaptive planning approach for the long-term development of airports. The next step would be to explore this possibility in more detail.
References


