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Adaptive Airport Strategic Planning

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Airport Strategic Planning (ASP) focuses on the development of plans for the long-term development of an airport. The dominant approach for ASP is Airport Master Planning (AMP). The goal of AMP is to provide a detailed blueprint for how the airport should look in the future, and how it can get there. Since a Master Plan is a static detailed blueprint based on specific assumptions about the future, the plan performs poorly if the real future turns out to be different from the one assumed. With the recent dramatic changes occurring in the context in which an airport operates (e.g., low cost carriers, new types of aircraft, the liberalization and privatization of airlines and airports, fuel price developments, the European Emission Trading Scheme), the uncertainties airports face are bound to increase. Hence, there is a great need for finding new ways to deal with uncertainty in ASP. An alternative direction is to develop an adaptive approach that is flexible and over time can adapt to the changing conditions under which an airport most operate. Three adaptive alternatives to AMP have been discussed in the literature. This paper explores these three alternative approaches. Based on this, it concludes that these approaches are complementary and that it might be worthwhile to combine the three into a new, adaptive approach to ASP. A design that integrates the key ideas from the three alternative approaches is presented and illustrated with a case based on Amsterdam Airport Schiphol.

Keywords: Airport strategic planning, Adaptive policymaking, Dynamic Strategic Planning, Flexible Strategic Planning, Uncertainty

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 has undergone unprecedented changes, exemplified by the rise of airline alliances and low cost carriers (Forsyth, 1998; de Neufville and Odoni, 2003). Parallel to this, the aviation industry has witnessed increasing environmental awareness, which has resulted in more attention being paid to the negative external effects of aviation, such as noise and emissions, and, since 9/11, safety and security are also of more concern. 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. All these changes together pose a major challenge for airports. They have to make

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investment decisions that will shape the future of the airport for many years to come, taking into consideration the many uncertainties that are present.

The current dominant approach for the long-term development of an airport is Airport Master Planning (AMP) (de Neufville and Odoni, 2003). 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). As such, the focus in AMP is on the development of plans and not on the decisionmaking process about the plans. Admittedly, the 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. ICAO, 1987; de Neufville and Odoni, 2003; IATA, 2004).

The goal of a Master Plan is to provide a blueprint that will determine the future development of the airport (Dempsey et al., 1997; Burghouwt and Huys, 2003). As such it describes the strategy of an airport operator for the coming years, without specifying operational concepts or management issues. A Master Plan covers both the aeronautical developments (i.e. runways, terminals) and non–aeronautical developments (e.g. real estate, commercial activities, and retail developments) of the airport. 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, but in general a time horizon of 20 years is used(FAA, 2005). AMP follows a strict linear process (de Neufville and Odoni, 2003):

- 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 preferred alternative into a detailed Master Plan

AMP, as the main way to shape and determine the long-term development of an airport, has proven to be ineffective, as can be seen for example in planning failures at Amsterdam Airport Schiphol, Denver International Airport, Boston Logan Airport, and Montréal Mirabel Airport. In 1995, a plan for the long-term development of Amsterdam Airport Schiphol was accepted. This plan had a time horizon of 20 years, but was obsolete in 1999, due to the unanticipated rapid growth of aviation demand (Kwakkel et al., 2007). The new Denver Airport was developed because of anticipated growth, which did not materialize. The new airport ended up with fewer air transport movements than took place at the old airport (Szyliowics and Goetz, 1995; Dempsey et al., 1997). Boston Logan planned and started the construction of a new runway in the early 1970's, but, due to unanticipated changes in regulations and strong stakeholder opposition, they were unable to open this runway until 2006 (Nelkin, 1974; Nelkin, 1975; Cidell, 2004; Kwakkel et al., 2007). Montréal Mirabel Airport was constructed in 1975 and was forecast to handle 40 million passengers by 2025. However, the airport failed to attract significant travel and was closed for passenger traffic in 2004 (Canadian Press, 2006). Given the ongoing transition of the aviation industry from a state-owned and state-run enterprise to a market situation, with its associated changes in how the public and the government view the aviation industry, the number and severity of the uncertainties is only expected to increase. In light of this, Master Planning becomes even less appropriate for long-term airport planning. In response to this problem of the inadequacy of AMP for ASP, the identification and analysis of alternative approaches has become more urgent. Several alternatives to AMP have been proposed in the literature (de Neufville, 2000; Burghouwt, 2007; Kwakkel et al., 2007). However, these new approaches are not fully developed, have not been applied in practice, have net yet been compared with each other, nor has their performance compared to AMP been assessed (Burghouwt, 2007). The aim of this paper is to describe and compare the available alternatives to AMP discussed in the airport planning literature, and to synthesize these alternatives into a single approach to ASP that is better equipped to deal with the many and diverse uncertainties airport planners face in the long-term development of an airport.

Following the earlier literature on long-term airport planning, we approach airport planning from a 'research and analyze' perspective (Mayer et al., 2004). Therefore, this paper does not consider the stakeholder and actor related problems associated with airport planning. In order to achieve the aim of comparing and synthesizing the alternative suggested approaches into a single approach to ASP that overcomes the problems associated with APM, we performed a literature review of the problems associated with APM. From these problems we derive criteria that alternative approaches have to meet to be a suitable alternative to APM. This literature review is presented in Section 2. Next, we performed a literature review of the alternative approaches to APM that have been put forward in the literature. We compare these approaches based on criteria derived at the end of Section 2. This review and comparison of alternatives to APM is presented in Section 3. From this comparison it is concluded that all alternatives have different strengths and weaknesses. A better approach can be created by synthesizing the alternatives into a single approach. This synthesized approach is presented in Section 4. Section 5 illustrates this new approach via a case focused on Amsterdam Airport Schiphol. Section 6 contains a discussion. Section 7 presents the conclusions.

2 Uncertainty in Airport Strategic Planning

AMP has been unsuccessful in planning the future development of airports. As the examples of Amsterdam Airport Schiphol, Denver International Airport, Boston Logan Airport, and Montréal Mirabel Airport illustrate, plans become quickly obsolete and are not robust with regard to the future. In other words, uncertainty (e.g. aviation demand, regulatory context, technological breakthroughs, and stakeholder behavior) is a key source of problems in ASP. In this section, we explore in more depth how uncertainty is currently treated in AMP, why this treatment is inadequate, and what this implies for alternative treatments.

The main way in which uncertainty is handled in AMP is through aviation demand forecasting. Forecasting has a long history in transport planning in general. The different techniques that are used in forecasting have been debated for a long time. A full review of this literature is beyond the scope of this paper; instead, we focus on the aviation planning literature.

2.1 The Challenge of Uncertainty for Airport Master Planning

The aviation demand forecast is the basis for a new Master Plan. An aviation demand forecast can be a forecast for the number of passengers, the tons of goods, or the number of air transport movements, although the forecast usually contains information concerning all three. For example, the forecast used for the plan for the long-term development of Schiphol in 1995 was a forecast of aviation demand for 2015 in terms of passengers. Given the average number of passengers on an airplane, this was translated into a forecast for air transport movements. By comparing the forecast with the existing conditions at an airport, an assessment can be made whether there is a need for new or expanded facilities. As such, aviation demand forecasting is the main way in which uncertainties about the future context in which an airport operates are handled. The basic concept of developing an aviation demand forecast is simple: past trends, based on time series or theories about underlying mechanisms, are identified and extrapolated forward. In mathematical terms, a relationship between independent variables (X_1, X_2, …, X_n) and the dependent variable (Y) is developed that matches aviation demand observed in the past. The resulting model is then used for extrapolation in order to obtain a forecast for the year of interest (FAA, 2001).

Forecasting in general has come under increasing criticism. The criticisms can be split into two categories: forecasting failure due to bias and forecasting failure due to uncertainty. Forecaster bias contributes to forecast failure in several ways. Forecasters often integrate political wishes into their forecasts (Flyvbjerg et al., 2003). Forecasts by project promoters may be even more biased, since the promoter has an interest in presenting the project in as favorable a light as possible (Flyvbjerg et al., 2003).

Forecasting failure due to uncertainty manifests itself in several ways. As pointed out by Flyvbjerg *et al*. (2003), discontinuous behavior of the phenomena we try to forecast, unexpected changes in exogenous factors, unexpected political activities, and missing realization of complementary policies are important reasons for forecasting failure. Ascher (1978) sees faulty core assumptions as a prime reason for forecasting failure. Faulty core assumptions refers to the fact that, since the phenomenon we are trying to forecast is not completely understood, forecasters have to make assumptions about the data they need, the formulas to be used, etc. (Porter et al., 1991). With respect to data, there are also several uncertainties. Forecasters often have a poor database that has internal biases caused by the data collection system, and they use data from their home countries (instead of the local areas) for calibrating their models (Flyvbjerg et al., 2003). In addition, forecasters have a tendency to misjudge the relevance of (recent) data (Porter et al., 1991). Despite these problems with data, forecasters still rely heavily on historic data for testing the adequacy of a forecast. However, there are an infinite number of formulas possible that can match the given historical data. Related to this is the fact that, in order to forecast a dependent variable Y based on a formula $Y = f(X_1, X_2, \ldots, X_n)$, forecasts are needed for the future values of the n independent variables. Instead of forecasting a single variable, one ends up forecasting n variables. Even if the problems associated with forecaster bias are addressed, forecasting failure due to uncertainty means that forecasting can always go wrong. By looking at the past and assuming that past behavior will continue into the future, uncertainties leading to trend breaks are overlooked, which, in most cases, are the uncertainties with the largest impacts on the system.

In the case of aviation demand forecasting, forecasting failure due to uncertainty is of specific importance. Over the last twenty years, the aviation industry worldwide has undergone exceptional changes. It has moved from a heavily regulated, state-owned, state-operated industry, towards a fully privatized industry. Currently, aviation transport in the US and Europe is largely privatized, while other regions in the world are moving in this direction as well. The net result of this privatization is that there have been unprecedented changes in the air transport sector, exemplified by the KLM-Air France merger, the rise of airline alliances, the US-EU Open Skies treaty, the rise of low cost carriers (LCC), and fierce competition between airports in order to attract carriers. Burghouwt (2007) has studied how airline networks evolved in Europe over time during these changes and concludes that air traffic demand is becoming more volatile and more uncertain, implying that forecasting air traffic demand for specific airports is becoming ever more problematic.

Apart from the fact that aviation demand forecasting is highly problematic in light of the many uncertainties that are present, there are several additional reasons that make aviation demand forecasting as the main way to treat uncertainty in AMP inadequate. First, usually only a single aviation demand forecast is generated. The airport Master Plan is designed based on this specific forecast. By making only a single forecast, however, one runs the risk of severely underestimating the range within which future aviation demand might develop. Second, there are many uncertainties present when developing plans for the long-term development of an airport. Aviation demand is only one such uncertainty. Other uncertainties include, among others, regulatory developments, technological developments, and demographic developments.

Aviation demand forecasting does not consider these, and, as a result, these other uncertainties are often ignored in the AMP process. Third, the Master Plan that results from the AMP process has a blueprint character (Burghouwt and Huys, 2003). The plan is drafted during the planning phase and is then handed over for implementation. During the implementation phase, the plan is implemented without much consideration for changing conditions. As a result, the Master Plan is static in nature and leaves little room for adapting to changing conditions. An analysis of the current long-term planning process of Amsterdam Airport Schiphol revealed that many uncertainties in addition to demand are not explicitly treated, and of those uncertainties that are addressed, most are addressed by making specific assumptions that are just estimates, rather than ranges of values (Kwakkel et al., 2008).

2.2 Criteria for a New Planning Approach

We can summarize the preceding discussion by saying that AMP is inadequate for the long-term development of airports, because the resulting plan is not robust with respect to future developments. This lack of robustness is the result of the fact that (a) very few uncertainties are addressed – usually only aviation demand uncertainties; (b) only a single future demand is considered, instead of a range of plausible demands; and (c) a Master Plan is static. In light of this, an alternative planning approach for long-term development that would deal better with the many uncertainties airport planners face should be designed to meet several criteria:

1. the planning approach should consider many different types of uncertainties, in addition to demand uncertainties;
2. the planning approach should consider many different plausible futures;
3. the resulting plan should be robust across the different futures;
4. the resulting plan should be flexible.

Admittedly, there are many other criteria that a planning approach for the long-term development of an airport should meet, which relate more to implementation of the new planning approach. For example, the approach should be easy to execute, not require too many resources, not be too time consuming, consider the different stakeholders that are affected, contain arrangements for stakeholder involvement, and so on. However, in this paper we are concerned primarily with the problems uncertainty causes for the long-term planning of airport development. Hence, we are interested in finding a new approach that can address uncertainty better then the current Master Planning approach. For the purposes of this paper, therefore, we do not consider these additional criteria (but, we do keep them in mind).

3 Adaptive Approaches for Airport Strategic Planning

Initial ideas on adaptive policies are found early in the 1900s. Dewey (1927) put forth an argument proposing that policies be treated as experiments, with the aim of promoting continual learning and adaptation in response to experience over time (Busenberg, 2001). Early applications of adaptive policies, called Adaptive Management, can be found in the field of environmental management (Holling, 1978). Motivated by the complexity of the environmental system, managers resort to controlled experiments aimed at increasing their understanding of the system (McLain and Lee, 1996). Or, as Lee (1993) puts it, adaptive policies are 'designed from the outset to test clearly formulated hypotheses about the behavior of an ecosystem being changed by human use'.

A recent development that is related to adaptive policies is the discussion about 'deep uncertainty' and its implications for the development of robust long-term policies. Decisionmaking under deep uncertainty is understood as a situation in which decisionmakers do not know or cannot agree on a system model, the prior probabilities for the uncertain parameters of the system model, and/or how to value the outcomes (Lempert et al., 2002). Lempert (2002) presents exploratory modeling as a method for the systematic analysis of large ensembles of potential futures. This method can be used to identify key uncertainties that influence policy performance, thus enabling the policymakers to improve the robustness of their policies. The main area of application of exploratory modeling has been in the field of climate change (Lempert et al., 2003).

Recently, Walker et al. (2001) developed a structured, stepwise approach for adaptive policymaking. This approach differs from adaptive approaches in the field of environmental management in that the key sources of uncertainty are external forces outside the control of the policymakers, instead of arising out of the complexity of the system the policymakers are trying to manage. Since the sources of uncertainty are different, the approach also differs in several important respects from Adaptive Management. Most importantly, the approach advocates not only the development of a monitoring system but also the pre-specification of responses when specific trigger values are reached. This is now called "planned adaptation".

Scientific work in the field of adaptive policies starts from the explicit recognition of the many and severe uncertainties decisionmakers face. Instead of predicting what will happen, which is impossible in light of these uncertainties, these researchers try to develop policymaking approaches that allow implementation to begin prior to the resolution of all major uncertainties, with the policy being adapted over time based on new knowledge. Adaptation is an innovative way to proceed with the implementation of long-term (transport) polices despite the uncertainties. These policymaking approaches make adaptation explicit at the outset of policy formulation. Thus, the inevitable policy changes become part of a larger, recognized process and are not forced to be made repeatedly on an *ad-hoc* basis. Adaptive policies combine actions that are time urgent with those that make important commitments to shape the future, preserve needed flexibility for the future, and protect the policy from failure. In case of ASP, there are three alternatives to AMP discussed in the airport planning literature, all based on concepts of flexibility and adaptability. These three are de Neufville's Dynamic Strategic Planning (de Neufville, 2000; de Neufville, 2003; de Neufville and Odoni, 2003; Karlsson, 2003), Adaptive Policymaking (Kwakkel et al., 2007), and Flexible Strategic Planning (Burghouwt, 2007). Below we discuss these three approaches in more detail.

3.1 Dynamic Strategic Planning

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 and Odoni, 2003). DSP is an approach for making plans, particularly for infrastructure, 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 cannot 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 well known example of a real option is to make a land use reservation (this is also known as 'land banking'). Such a reservation offers planners the option to expand infrastructure in the future if this turns out to be needed.

There is no clear prescribed process for performing DSP, although there are seven distinct categories of methods and activities that together will result in a dynamic strategic plan. These are (de Neufville, 2000):

1. Modeling: this activity should result in one or more models of the technical system and its performance.
2. Optimization: this activity should result in an overview of different cost-effective means for achieving specified levels of results.
3. Estimation of probabilities: since the performance of a system in the future cannot be forecast, it is necessary to estimate the range of values for key system parameters and the likely probability distributions for these parameters.
4. Decision Analysis: by combining the results from the previous three activities, a Decision Analysis for the set of choices can be carried out.
5. Sensitivity Analysis: this activity should make sure that the outcome of the Decision Analysis is robust with regard to changes in parameter values.
6. Evaluation of Real Options: this activity should focus on identifying cost-effective real options that increase the flexibility of the plan. These can then be inserted into the Decision Analysis.
7. Analysis of implicit negotiation: the implementation of a plan is to a large extent dependent on the support of relevant stakeholders. This activity aims at analyzing the stakeholders and their possible behavior. The results are to be taken into account when thinking about the implementation of the plan that is developed through activities 1-6.

3.2 Adaptive Policymaking

Adaptive Policymaking (APM) is proposed as a generic approach for the treatment 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. 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 is 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 (i.e. plausible events or developments that would hamper the performance of the plan). 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 uncertain vulnerabilities, and actions are prepared to be taken when the monitoring reveals that specific vulnerabilities have manifested 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 of the policy is necessary.

3.3 Flexible Strategic Planning

Flexible Strategic Planning (FSP) has been suggested as an alternative to traditional AMP by Burghouwt (2007). He suggests that, 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. FSP draws heavily on DSP, but adds to this the notion of pro-active planning. An airport 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 are needed for traditional AMP.

3.4 A Comparison of the Three Approaches

Table 1 below gives an overview of some key characteristics of the three adaptive planning approaches. As a first element for comparison, we consider the focus of each approach. In light of the criteria for a new planning approach specified in Section 2.2, it is also relevant to identify the types of uncertainty that are considered in the three alternative planning approaches (Criterion 1), whether multiple futures are considered (Criterion 2), whether the resulting plan is robust (Criterion 3), and how flexibility is guaranteed in the plan (Criterion 4). Given our stated goal of proposing a new Airport Strategic Planning approach, it is also relevant to take into consideration to what extent these the three approaches provide a clear planning process. Table 1 can be used as a starting point for analyzing, comparing, and identifying a promising alternative planning approach to AMP.

Table 1. Comparison of Three Approaches for Adaptive Planning

Aspect	Dynamic Strategic Planning	Adaptive Policy Making	Flexible Strategic Planning
Focus	Flexibility in a plan created through real options	Starts from a vision of the decisionmaker and creates a plan for realizing this vision and protecting it from failure	Extends the focus of DSP by adding pro-active planning and contingency planning
Types of uncertainties considered	Emphasis on demand uncertainty, but other types of uncertainties could be considered as well via real options	Any uncertainty can be considered	Emphasis on demand uncertainties as driven by airline network developments, but in principle open to all types of uncertainties
Consideration of different futures	Via a staged development	Via hedging and mitigating actions	Via scenario robustness
Robustness of the resulting plan	No direct consideration of robustness, but a range of futures can be handled via real options	Explicit consideration of increasing robustness of plan via hedging and mitigating actions	Explicit consideration via use of scenarios
Flexibility of resulting plan	Flexibility of plan is guaranteed via real options	Flexibility of the plan is addressed via the establishment of a monitoring system and pre-specification of responses	Flexibility of the plan is guaranteed via real options and contingency planning
Planning process	Seven categories of activities specified, but their relationships to each other and how they constitute a planning process remain unclear	Has a clear planning process, with a distinction between a thinking phase and an implementation phase	No clear process is specified

As can be seen in Table 1, all three approaches meet the criteria specified in Section 2.2. The treatment of uncertainty in all three approaches moves beyond demand forecasting and makes use of additional techniques, such as real options, hedging, scenarios, and pro-activeness. These techniques all aim at making the plan more robust with respect to uncertainty about the future. The three approaches can consider all types of uncertainty, although DSP and FSP focus mainly on demand uncertainties. The three approaches can also be used to consider multiple different futures, although the way in which this is done differs. FSP explicitly includes the idea of multiple futures, since it intends to make use of scenarios. DSP considers multiple futures by only committing to a first stage of development while preparing different actions for future stages of development. In addition, with its insistence on forecasting failure, DSP also emphasizes the need for multiple forecasts based on different assumptions about future external developments. The idea of committing to a first set of actions while preparing others in advance can also be found in APM and is its main way of dealing with multiple futures. The three approaches differ with respect to the presence or absence of a clear planning process. FSP does not provide any description of a process. DSP provides only several categories of activities. Only APM has a clear process and framework that, if followed carefully, will result in a complete adaptive plan that can be implemented by policymakers.

The idea of committing to a first set of actions while preparing others in advance is of specific importance in infrastructure planning and development, because of the time it takes to build new infrastructure. For example, in the case of airport development, implementing a new runway can take ten years or more. Over this period however, significant changes can occur that would render the investment superfluous. Adaptive approaches suggest that, where possible, the investments should be phased. To continue the example of runway expansion, in the first phase, the land could be acquired. Next, if the runway still appears to be necessary, the groundwork could be carried out. If, after this, the runway is still required, the next phase of construction could start. By phasing the infrastructure investment, the risks of superfluous investments can at least be partly mitigated. By phasing the development of new infrastructure, the flexibility to respond to changing conditions is retained, reducing the risk of unnecessary investments.

Based on Table 1, we conclude that the three approaches are all capable of dealing with the many and diverse uncertainties airport planners face, although this capability is realized in different ways. DSP uses real options as the main mechanism to create a flexible plan. APM forces planners to consider many and diverse uncertainties and to prepare for these in advance through hedging and mitigating actions. The successful execution of the plan is also taken into account via the pre-specified monitoring system. FSP is perhaps the broadest in terms of the available ideas and notions for the treatment of uncertainty, with its discussion of robustness, hedging, diversification of revenues, and its insistence on pro-activeness. FSP is, however, also the least developed planning approach in terms of its operationalization. In light of the different angles by which the approaches address uncertainty, it is important to note that these angles are not contradictory. Real options, for example can be used as a means for creating a mitigating or hedging action in the context of APM. In light of all the above, it appears that it might be possible to design an improved approach for ASP by combining ideas from these three approaches. This synthesis can draw on the relative strengths of the different approaches, such that the resulting synthesis is better equipped to overcome the weaknesses of AMP than any of the three approaches individually. Another benefit of designing a single approach is that researchers can concentrate their efforts on further developing and testing this single approach instead of spreading their efforts over all of them or focusing on one of them. This is especially relevant in light of the fact that all three approaches are still in their conceptual stages and significant work is required before any of the approaches can be used in practice, as noted by Burghouwt (2007) and (Hansman et al., 2006).

4 A Synthesized Approach to Adaptive Airport Strategic Planning

In light of the fact that only APM has a well developed planning process, we use it as the starting point for developing an integrated adaptive approach for ASP, which we call Adaptive Airport Strategic Planning (AASP). The main idea from DSP is the real options concept. Real options in the context of APM can be used as a means to create adaptive actions (e.g. hedging actions). A key idea of FSP that is not explicitly part of APM is the notion of proactive planning. APM can be expanded to cover this in a straightforward manner by recognizing that uncertain future developments can be two sided. Some external changes can cause a policy to fail, while other changes can make a policy more successful. So, the future presents a strategic planner both with vulnerabilities that can cause a policy to fail and with opportunities that can improve the policy's success. Pro-activeness can then be integrated into APM by including actions that try to shape the

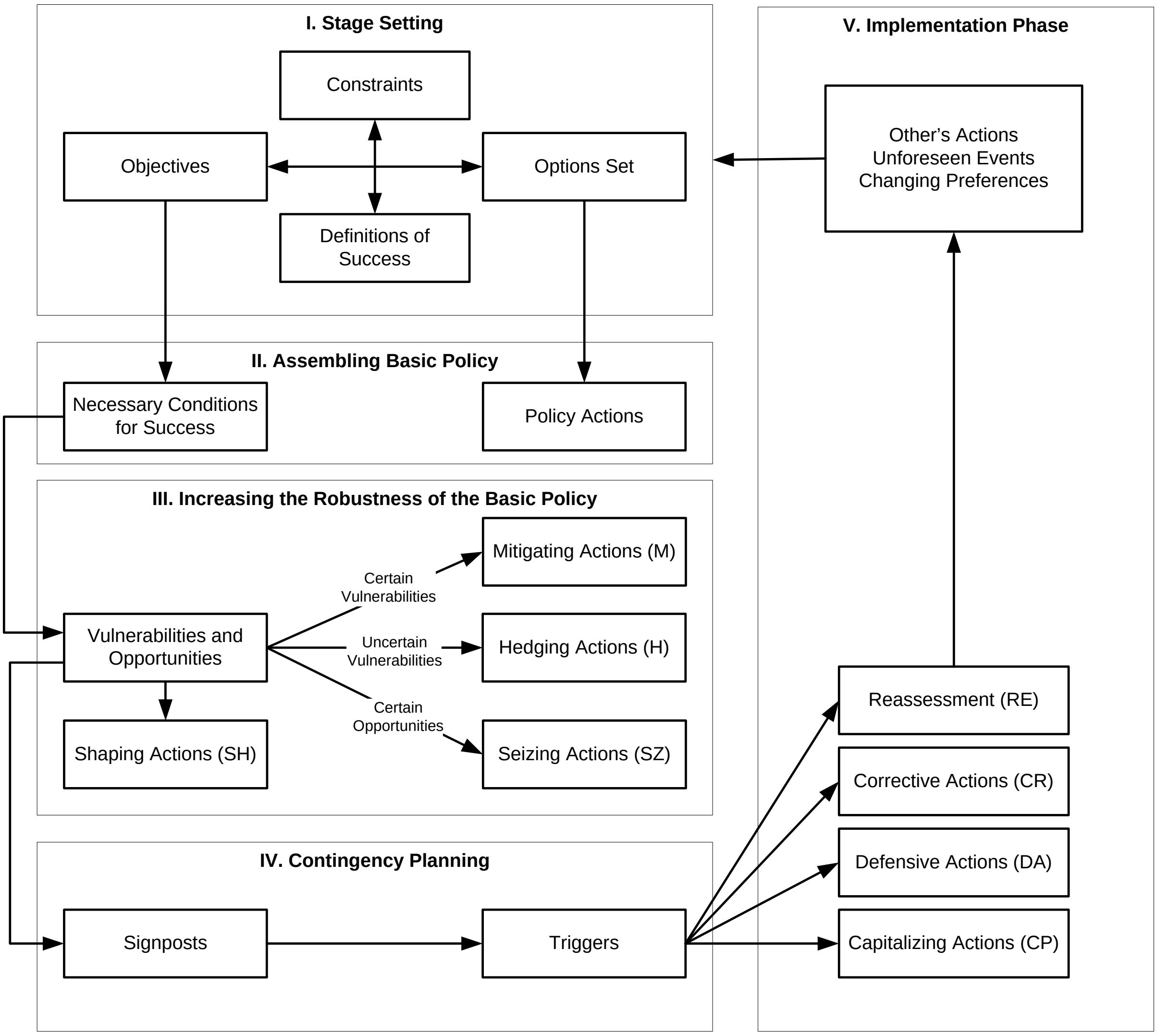

Figure 1. The Steps of Adaptive Airport Strategic Planning (AASP)

nature of a vulnerability, and by including actions that aim at taking advantage of opportunities when they present themselves. Other relevant ideas from FSP are robustness and contingency planning, although both are already incorporated in APM. Robustness is covered in the form of hedging and mitigating actions. Contingency planning is present in the form of the monitoring system and its associated actions that are triggered if threshold values are reached on the signposts. Figure 1 presents the expanded APM framework. Note that in this paper the term 'policy' does not refer to government policies, such as regulations, but refers to airport plans or strategies, such as adding a runway or building a new terminal. In the context of adaptive policymaking, such plans can also contain actions that prepare the airport for the future without directly changing the system. This is in contrast to traditional policy analysis, in which policies are the set of forces within the control of the actors in the policy domain that affect the structure and performance of the system (Walker, 2000).

4.1 Step I (Stage Setting) and Step II (Assembling the Basic Policy)

Both the first and second steps are similar to the current steps in AMP. The first step constitutes the stage-setting step (e.g. analyzing the existing conditions of an airport). This step involves the specification of objectives, constraints, and available policy options (e.g. expand the terminal, build a new terminal, add a new runway, or extend an existing runway). This specification should lead to a definition of success, in terms of the specification of desirable outcomes (e.g. desired noise levels, number of houses in noise contours, number of air transport movements served at the airport, minimum average delay of aircrafts). In the next step, a basic policy is assembled. It involves (a) the specification of a promising policy and (b) the identification of the conditions needed for the basic policy to succeed.

4.2 Step III (Robustness)

In the third step of the adaptive policymaking process, the robustness of the basic policy is increased. This step is based on identifying in advance the vulnerabilities and opportunities associated with the basic policy, and specifying actions to be taken in anticipation or in response to them. The key element of this step is the identification of vulnerabilities and opportunities. Vulnerabilities are possible developments that can degrade the performance of a policy so that it is no longer successful. Opportunities are developments that can increase the success of the policy. For example, an important vulnerability of most airport Master Plans is that demand turns out to be lower than anticipated, rendering investment in capacity expansion superfluous. But, demand might also develop rapidly, allowing the airport to expand faster then anticipated. In this case, the same uncertain external development can be both a vulnerability and an opportunity. There are two basic ways of preparing a policy for vulnerabilities and opportunities, either by taking actions now, or by preparing actions in advance that can be taken in the future if necessary (the latter is considered in Step IV). There are four different types of actions that can be taken in advance in anticipation of specific contingencies or expected effects of the basic policy:

- *mitigating actions (M)* – actions to reduce the *certain* adverse effects of a policy;
- *hedging actions* (H) – actions to spread or reduce the risk of *uncertain* adverse effects of a policy;
- *seizing actions (SZ)* – actions taken to seize certain available opportunities;
- *shaping actions (SH)* – actions taken to reduce the chance that an external condition or event that could make the policy fail will occur, or to increase the chance that an external condition or event that could make the policy succeed will occur.

Mitigating actions and hedging actions prepare the basic policy for potential adverse effects and in this way try to make this policy more robust. Seizing actions are actions taken now to change the policy in order to seize available opportunities. In contrast, shaping actions are pro-active and aim at affecting external forces in order to reduce the chances of negative outcomes or to increase the chances of positive outcomes. As such, shaping actions aim not so much at making the plan more robust, but at changing the external situation in order to change the nature of the vulnerability or opportunity. For example, marketing is an attempt to increase the demand for a given product. In this way, one tries to prevent insufficient demand for the product (Dewar, 2002). Real options can be used as a technique for any of these four types of actions. For example, if an airport plans to expand its terminal capacity, it faces the vulnerability of insufficient demand. A real option's design of the terminal (e.g. in a modular way) is then a hedging action against insufficient demand.

4.3 Step IV (Contingency Planning)

Even with the actions taken in advance, there is still the need to monitor the performance of the policy and take action if necessary. In the fourth step, the policy is further expanded via contingency planning, in which the robust basic policy is further enhanced by including adaptive elements. The first element of the contingency plan is the identification of signposts. Signposts specify information that should be tracked in order to determine whether the policy is achieving its conditions for success. The starting point for the identification of signposts is the set of vulnerabilities and opportunities specified in Step III. Critical values of signpost variables (triggers) are specified, beyond which actions should be implemented to ensure that a policy keeps moving the system in the right direction and at a proper speed. Some of these actions might be prepared in advance and might require a change to the basic policy. To continue our example of the terminal from Step III, the development of demand is something the airport should monitor closely. In light of how the demand develops, new modules can be added to the modular terminal. If demand grows rapidly, the terminal can easily be expanded, while if demand does not grow as fast as anticipated, further extensions can be delayed. As is shown by this example, real options can also form part of the contingency planning part of the plan. Again, the opportunity side of the vulnerabilities should also be considered in this step.

There are four different types of actions that can be triggered by a signpost:

- *defensive actions (DA)* – actions taken *after the fact* to clarify the policy, preserve its benefits, or meet outside challenges in response to specific triggers that leave the basic policy remains unchanged;
- *corrective actions (CR)* – adjustments to the basic policy in response to specific triggers;
- *capitalizing actions (CP)* – actions taken *after the fact* to take advantage of opportunities that further improve the performance of the basic policy;
- *reassessment (RE)* – a process to be initiated or restarted when the analysis and assumptions critical to the policy's success have clearly lost validity.

4.4 Step V (Implementation)

Once the basic policy and additional actions are agreed upon, the final step involves implementing this entire plan. In this step, the actions to be taken immediately (from Step II and Step III) are implemented and a monitoring system (from Step IV) is established. Then time starts running, signpost information related to the triggers is collected, and policy actions are started, altered, stopped, or expanded. After implementation of the initial mitigating, hedging, seizing, and shaping actions, the adaptive policymaking process is suspended until a trigger event occurs. As long as the original policy objectives and constraints remain in place, the responses to a trigger event have a defensive or corrective character – that is, they are adjustments to the basic policy that preserve its benefits or meet outside challenges. Sometimes, opportunities are identified by the monitoring system, triggering the implementation of capitalizing actions. Under some circumstances, neither defensive nor corrective actions might be sufficient to save the policy. In that case, the entire policy might have to be reassessed and substantially changed or even abandoned. If so, however, the next policy deliberations would benefit from the previous experiences. The knowledge gathered in the initial adaptive policymaking process on outcomes, objectives, measures, preferences of stakeholders, etc., would be available and would accelerate the new policymaking process.

5 Application of Adaptive Airport Strategic Planning to the Case of Schiphol Airport

In this section, we illustrate the approach outlined in the previous section through a case. For an effective illustration, a single in-depth case is preferred over several small cases. Given that AASP is intended to improve upon AMP under conditions of uncertainty, the case needs to have a multitude of different uncertainties. These uncertainties should cover the full range of uncertainties to which airports around the world are exposed. We choose to use the current challenges Schiphol faces in its long–term development as our case. As outlined below, Schiphol faces a range of uncertainties that could affect the airport in different ways. In addition, we are familiar with the current situation of Schiphol; the uncertainties the airport currently faces have been studied recently (Kwakkel et al., 2008), and a multitude of policy documents from multiple stakeholders is available (e.g. CPB et al., 2007; Provincie Noord-Holland, 2007; Schiphol Group, 2007; Schiphol Group and LVNL, 2007; V&W, 2007; V&W and VROM, 2007; Rijksoverheid, 2009).

Aviation demand has experienced unprecedented growth since the early 1990's, fuelled by privatization and liberalization of the aviation industry. Amsterdam Airport Schiphol has benefited from this growth and has evolved into one of the European Union's major hubs. Since 1990, Schiphol has expanded its runway system and its terminal. Parallel to the increasing number of passengers and flights handled at Schiphol, negative external effects have also increased, resulting in regulations concerning noise, emissions, and third-party risk.

Currently, Schiphol's position as a hub within Europe is under pressure. In 2006, Schiphol was surpassed by Madrid's Barajas Airport 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, Schiphol's hub carrier, which is responsible for 52% of the scheduled aircraft movements at the airport, might move a significant portion of its operations to Charles de Gaulle Airport. The other major airports in Europe are planning on expanding their capacity or are developing dual airport systems, while Schiphol's capacity is under threat of being reduced do to climate change induced deterioration of wind conditions. Together, this makes the long-term planning for Schiphol both urgent and problematic.

In the remainder of this section, we illustrate how each of the steps of the new adaptive policymaking approach might be applied to the case of the long-term development of Schiphol. The purpose of this extensive case is two-fold. First, it is intended to illustrate the adaptive approach described in Section 4 and clarify how the concepts could be applied in practice. Second, it serves as a first face-validation of the outlined approach. To give the reader a sense of how this approach could work in the real world, we use the example of a real airport (Schiphol) instead of a made-up airport. However, to make the approach clear and understandable, the example simplifies some of the key challenges Schiphol faces. Therefore, this case should not be understood as presenting a realistic plan for the long-term development of Schiphol. It is merely an example loosely based on real policy issues and policy debates that policymakers are currently facing with respect to the long-term development of an airport.

5.1 Step I: Specification of Objectives, Constraints, and Available Policy Options

The Schiphol Group is primarily interested in medium- to long-term developments until 2020. As outlined in its current long-term vision (Schiphol Group and LVNL, 2007), the main goals of the Schiphol Group are: (1) to create room for the further development of the network of KLM and its Skyteam partners, and (2) to minimize (and, where possible, reduce) the negative effects of aviation in the region. Underlying the first goal is the implicit assumption that aviation will continue to grow. However, in light of recent developments such as peak oil and the financial crisis, this assumption is questionable. It might be better to rephrase this first goal more neutrally as 'retain market share'. If aviation in Europe grows, Schiphol will have to accommodate more demand in order to retain its market share, while if aviation declines, Schiphol could still reach its goal of retaining market share.

There are several types of changes that can be made at Schiphol in order to achieve its goals of retaining market share and minimizing the negative effects of aviation. Schiphol can expand its capacity by using its existing capacity more efficiently and/or building new capacity. It can also expand its capacity or use its existing capacity in a way that mitigates the negative effects of aviation. More explicitly, among the policy options that Schiphol might consider are:

1. Add a new runway
2. Add a new terminal
3. Use the existing runway system in a more efficient way, in order to improve capacity
4. Use the existing runway system in a way that minimizes noise impacts
5. Move charter operations out of Schiphol (e.g., to Lelystad)
6. Move Schiphol operations to a new airport (e.g., in the North Sea)
7. Invest in noise insulation

Some of these policies can be implemented immediately (e.g., using the existing runway system in a more efficient way). For others, an adaptive approach would be to begin to prepare plans and designs (e.g., for a new runway), but to begin actual building only when conditions show it to be necessary (i.e., when it is triggered). The various options can, of course, be combined. The changes that can be made are constrained by costs, spatial restrictions, public acceptance, and the landside accessibility of Schiphol. The definition of success includes that Schiphol maintains its market share and that living conditions improve compared to some reference situation (e.g. number of people affected by noise within a specified area).

5.2 Step II: Basic Policy and its Conditions for Success

A basic policy might be to immediately implement existing plans for using the runways more efficiently (option 3) and in a way that reduces noise impacts (option 4). It might also include all policy options that focus on planning capacity expansions, without beginning to build any of them (i.e. options 1, 2, and 5). A final element of the basic policy would be option 7: invest in noise insulation. The choice for only planning capacity expansions but not yet building them is motivated by the fact that Schiphol is currently constrained by the environmental rules and regulations, not by its physical capacity. This also motivates the choice for options 3 and 4, which together can reduce the negative externalities of aviation.

The most discussed option for the new runway is to place it parallel to one of the existing runways – the Kaagbaan. There are several arguments for this choice. First, it would improve the capacity of Schiphol under crosswind conditions in case of a southwesterly storm, making the peak-hour capacity throughout the year more sustainable. This is of particular importance given climate change induced changes in wind regime. Currently, the Oostbaan is used for landings under these crosswind conditions. However, incoming aircraft that use the Oostbaan have to come in over the center of Amsterdam, which produces significant noise nuisance. Furthermore, the Oostbaan cannot handle the larger passenger aircraft. Schiphol would prefer to replace the Oostbaan with the new parallel Kaagbaan. This runway would create less noise nuisance, can handle larger aircraft, can be operated independently from the current Kaagbaan, and can, if necessary, also be used for take-off operations.

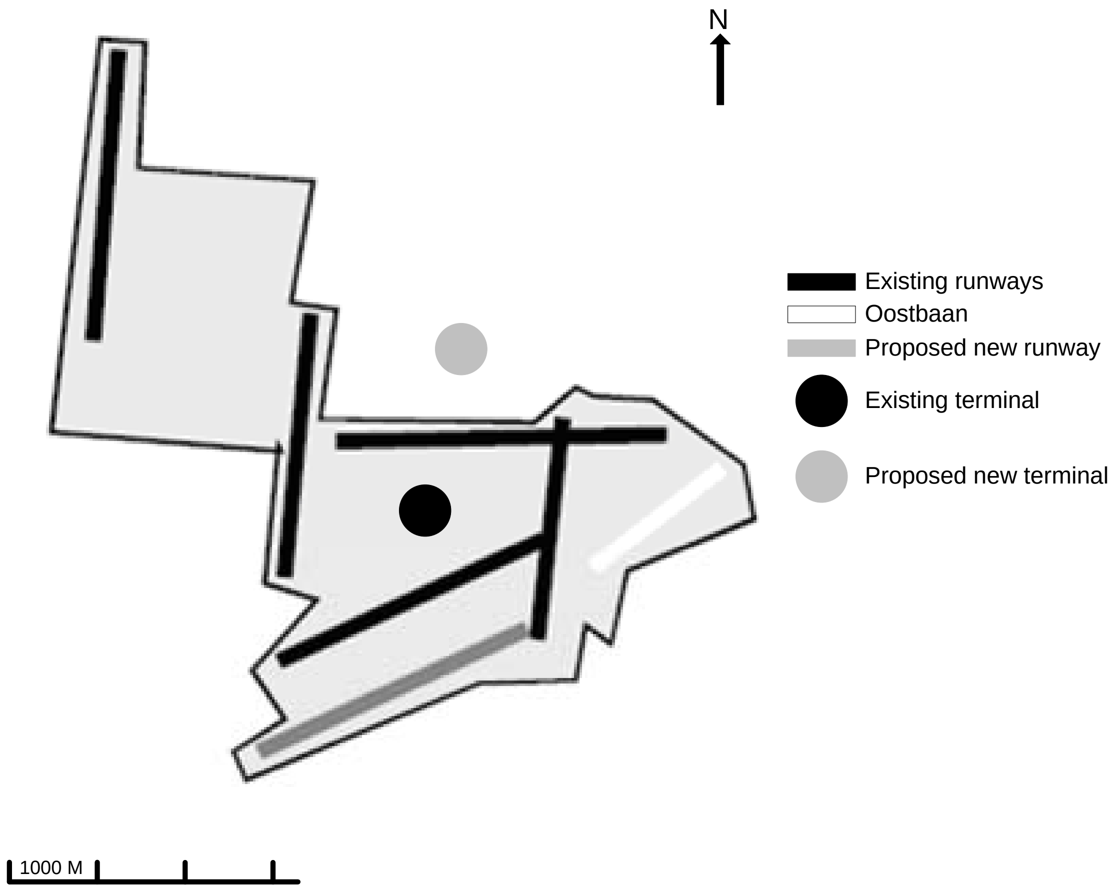

Figure 2. The planned extensions to Amsterdam Airport Schiphol

The current terminal design of Schiphol is based on a single terminal concept. The available space for further expanding the existing terminal is, however, limited. Therefore, if Schiphol wants to expand its terminal capacity, a new terminal on a different location has to be developed. The basic policy could include a plan for a separate dedicated terminal for LCC's located away from the existing terminal (black circle in Figure 2). This is an option that Schiphol is currently considering.

In addition to these capacity expansions, Schiphol might begin to develop plans to move charter operations to Lelystad airport, which would reduce noise around Schiphol and increase Schiphol's capacity for regular flight operations. In order to realize such a move, Lelystad Airport would need to be expanded considerably, so planning should be started right away. Charter operations should then be moved there as soon as possible. In the short run this would create additional capacity and reduce noise at the edges of the night, which is favorable for Schiphol, because the current noise regulation system heavily penalizes flights in the evening (19.00-23.00) and during the night (23.00-07.00).

In light of Schiphol's goals (retaining market share and minimizing the negative effects of aviation (Schiphol Group and LVNL, 2007)), several necessary conditions for the success of the basic policy can be specified:

- Schiphol should retain its current market share

- The population affected by noise and the number of noise complaints should not increase
- Schiphol's competitive position in terms of available capacity in Europe should not decrease
- Schiphol's landside accessibility should not deteriorate

5.3 Step III: Vulnerabilities and Opportunities of the Basic Policy, and Anticipatory Actions

The long-term development of Schiphol is complicated by the many and diverse trends and developments that can affect Schiphol. These developments and trends present both opportunities and vulnerabilities. Some of these vulnerabilities are relatively certain. These are given in Table 2. Two certain vulnerabilities are resistance from stakeholders and a reduction of the landside accessibility. The mitigating actions for addressing these vulnerabilities are very similar to actions currently being discussed by the Government (V&W and VROM, 2007). A shaping action for the vulnerability of landside accessibility is investment in research. In addition to vulnerabilities, there are currently also some opportunities available to Schiphol. First, recent work shows the potential for 'self-hubbing' (Burghouwt, 2007; Malighetti et al., 2008). Self-hubbing means that passengers arrange their own flights and routes, using low cost carriers or a variety of alliances, in order to minimize costs and/or travel time. Schiphol has a great potential for attracting such self-hubbing passengers because it connects 411 European cities (Malighetti et al., 2008). Schiphol can seize this opportunity by developing and implementing services tailored to self-hubbing passengers, such as services for baggage transfer and help with acquiring boarding passes. Furthermore, Schiphol could take into account walking distances between connecting European flights when allocating aircraft to gates. A second opportunity is presented by the fact that airports in general, and Schiphol in particular, are evolving into 'airport cities'. Given the good transport connections available, an airport is a prime location for office buildings. Schiphol can seize this opportunity by investing in non-aeronautical landside real estate development.

Table 2. Certain Vulnerabilities, and Responses to Them

Vulnerabilities and Opportunities	Mitigating (M), Shaping (SH) and Seizing (SZ) Actions
Reduction of the landside accessibility of the airport.	M: develop a system for early check-in and handling of baggage at rail-stations SH: invest in R&D into the landside accessibility of the Randstad area.
Resistance from Schiphol stakeholders (e.g. environmental groups, people living around Schiphol)	M: develop plans for green areas to compensate for environmental losses. M: offer financial compensation to residents in the high noise zone
Rise of self-hubbing	SZ: design and implement a plan for supporting self-hubbing passengers with finding connection flights, transferring baggage, and acquiring boarding passes
Rise of the airport city	SZ: Diversify revenues by developing non-aeronautical landside real estate

Not all vulnerabilities and opportunities are certain. The real challenge for the long-term development of Schiphol is presented by the uncertain vulnerabilities and opportunities. Table 3 presents some of the uncertain vulnerabilities together with possible hedging (H) and shaping actions (SH) to take right away to handle them. The vulnerabilities and opportunities can be directly related and categorized according to the success conditions specified in the previous step. With respect to the success condition of growing demand, air transport demand might develop significantly different from what is hoped and anticipated. Schiphol can respond to this development by making Lelystad airport suitable for handling non–hub–essential flights. Another vulnerability is that KLM might decide to move a significant part of its operations to

Charles de Gaulle. This will leave Schiphol without its hub carrier, significantly reducing demand, and changing the demand to origin-destination demand. Schiphol could prepare for this vulnerability by making plans for adapting the terminal to the requirements of an O/D airport and by diversifying the carriers that serve Schiphol. Schiphol can also try to directly affect KLM by investing in a good working relationship, reducing the chance that KLM will leave. Currently, there is an ongoing debate about the future of the hub-and-spoke network structure. Due to the Open Sky agreements and the development of the Boeing 787, long-haul low-cost, hub bypassing, and self-hubbing become plausible, resulting in the emergence of long-haul low-cost carriers and increasing transfer between short–haul low–cost, and long–haul carriers (both LCC and legacy carriers). Schiphol can prepare for this by developing a plan to change its current terminal to serve a different type of demand and by taking these plausible developments into consideration when designing the new LCC terminal and its connection with the existing terminal. If a transformation to international origin-destination traffic and/or a no-frills airport is needed, this plan can be implemented, making sure that the transformation can be achieved quickly

The second success condition is that the population affected by noise and the number of noise complaints should not increase. Vulnerabilities and opportunities associated with this condition are that the current trend of decrease of environmental impact of aircraft changes, the population density in the area affected by noise increases, and the valuation of externalities (predominantly noise) by the large public changes. If the current trend of decreasing environmental impact slows down, the area affected by noise will not continue to shrink if demand stays the same. If demand increases, it is possible that the area affected by noise will also increase. On the other hand, the trend could also accelerate, giving Schiphol the opportunity to expand the number of flights that is handled. Given the potential impact of this trend, Schiphol should try and shape its development by investing in R&D and negotiate with Air Traffic Control about testing noise abatement procedures, such as continuous descent approaches. If the population density changes, the situation is similar. If it increases, the number of people affected by noise will increase, while if it decreases, the number of people affected by noise will decrease. Schiphol can try and shape this development by negotiating with surrounding communities about their land use planning and invest in research that can make the area affected by noise smaller. It can also hedge against a growing population density by starting to test noise abatement procedures outside peak hours. This will make the area affected by noise smaller. Thus even if the population density increases, the total number of people affected will not increase. A third uncertainty is how the valuation of noise will change in the future. If noise will be considered more of a nuisance, complaints are likely to go up, and vice versa. Schiphol could try to affect this valuation by branding the airport as environmentally friendly and support the development of an emission trading scheme that also includes aviation.

The third success condition is that Schiphol's competitive position in terms of available capacity in Europe does not decrease. Schiphol is vulnerable to the capacity developments at other airports in Europe. The major hubs in Europe are all working on expanding their capacities, either by adding runways and expanding terminals, or by moving non-hub-essential flights to alternative airports in the region. Schiphol should monitor these developments closely and, if necessary, speed up its capacity investments. A second vulnerability is the robustness of Schiphol's peak-hour capacity across weather conditions. Under southwesterly wind conditions, Schiphol's hourly capacity is almost halved, resulting in delays and cancellations. If (e.g., due to climate change) these wind conditions were to become more frequent, Schiphol would no longer be able to guarantee its capacity. Schiphol should hedge against this by having plans ready for building the sixth runway.

Table 3. Uncertain Vulnerabilities and Opportunities, and Responses to Them

Vulnerabilities and Opportunities	Hedging(H) and Shaping(SH) Actions
Retain market share	
Demand for air traffic grows faster than forecast.	H: Prepare Lelystad airport to receive charter flights
Demand for air traffic grows slower than forecast.	SH: Advertise for flying from Schiphol
Collapse or departure of the hub carrier (KLM) from Schiphol.	H: Prepare to adapt Schiphol to be an O/D airport. H: Diversify the carriers serving Schiphol SH: Develop a close working relation with KLM
Rise of long-haul low-cost carriers	H: Design existing and new LCC terminal to allow for rapid customization to airline wishes
Rise of self-hubbing, resulting in increasing transfers among LCC operations	H: Design a good connection between the existing terminal and the new LCC terminal, first with buses, but leave room for replacing it with a people mover
Population affected by noise and the number of noise complaints should not increase	
Maintain current trend of decrease of environmental impact of aircraft	SH: Negotiate with air traffic control on investments in new air traffic control equipment that can enable noise abatement procedures, such as the continuous descent approach SH: Invest in R&D, such as noise abatement procedures
Increase in the population density in area affected by noise	H: Test existing noise abatement procedures, such as the continuous descent approach, outside the peak periods (e.g. at the edges of the night) SH: Negotiate with surrounding communities to change their land use planning SH: Invest in R&D, such as noise abatement procedures
Change in the valuation of externalities by the public	SH: Invest in marketing of the airport to brand it as an environmentally friendly organization SH: Join efforts to establish an emission trading scheme
Schiphol's competitive position in terms of available capacity in Europe does not decrease	
Other major airports in Europe increase capacity	No immediate action required
Development of wind conditions due to climate change	H: Have plans ready to quickly build the sixth runway, but do not build it yet. If wind conditions deteriorate even further, start construction

5.4 Step IV: Contingency Planning

Step IV sets up the monitoring system and identifies the actions to be taken when trigger levels of the signposts are reached. The vulnerabilities and opportunities are those presented in Table 3. Table 4 shows the signpost to be set up for each vulnerability and each opportunity, and the possible responsive actions in case of a trigger event. The numbers used as triggers are for illustrative purposes only. For example, if demand increases twice as fast as expected, this presents an opportunity and triggers capitalizing actions. If demand grows 25% slower then anticipated, this presents a threat to the policy. In reaction, investments in capacity are delayed or even cancelled. If demand fully breaks down or explodes, the policy should be reassessed.

Table 4. Contingency Planning

Vulnerabilities and Opportunities	Monitoring and Trigger System	Actions (Reassessment (RE), Corrective (CR), Defensive (DA), Capitalizing (CP))
Retain market share		
Demand for air traffic grows faster than forecast.	Monitor the growth of Schiphol in terms of passenger movements, aircraft movements (and related noise and emissions), if double demand (trigger) take CP-action. If demand explodes, take RE-action.	CP: Begin to implement the plan for the new terminal and the new runway RE: Reassess entire policy
Demand for air traffic grows slower than forecast.	Monitor types of demand. If overall demand is decreasing by half of forecast, take D-actions. If demand fully breaks down, take RE-action. If transfer rate decreases below 30% take CR-action.	DA: Delay investments, and reduce landing fees RE: Reassess entire policy CR: Cancel terminal capacity expansions
Collapse or departure of the hub carrier (KLM) from Schiphol.	Monitor the network of KLM-Air France, if 25% of flights are moved take DA-action, if 50% take CR-action, if 80% or more take R-action.	DA: Diversify the carriers that fly from Schiphol CR: Switch airport to an O/D airport by changing terminal RE: Reassess entire policy
Rise of long haul low cost carriers	Monitor development of the business model of low cost carriers. If long-haul LCC carriers make profit for 2 years take CP-action.	CP: Attract long haul LCC by offering good transfer between LCC terminal and existing terminal and/or by offering wide body aircraft stands at the LCC terminal
Rise of self-hubbing, resulting in increasing transfers between LCC operations	Monitor transfer rate among LCC flights and between LCC and legacy carriers. If transfer rate becomes more then 20%, take CP-action.	CP: Expand transfer capabilities between the new LCC terminal and the existing terminal
Population affected by noise and the number of noise complaints should not increase		
Maintain current trend of decrease of environmental impact of aircraft	Monitor noise footprint and emissions of the fleet mix serving Schiphol and of the new aircraft entering service. If there is an increase of noise or emissions of 10%, take CR-action.	CR: Change landing fees for environmentally unfriendly planes
Increase in the population density in area affected by noise	Monitor population affected by noise. If population affected by noise increases by 2%, take DA-action; by 5%, take CR-action; by 7.5%, take R-action. If population density decreases by 2%, take CP-action.	DA: Expand insulation program and explain basic policy again CR: Slow down of growth by limiting available slots RE: Reassess entire policy CP: If the population density decreases, make new slots available.
Change in the valuation of externalities by the large public	Monitor the complaints about Schiphol. If complaints increase by an average of 5% over 2 years, take DA-action. If complaints increase by an average of 10% or more over 2 years, take CR-action.	DA: Increase investments in marketing and branding CR: Slow down the growth of Schiphol by limiting the available slots
Schiphol's competitive position in terms of available capacity in Europe does not decrease		
Other major airports in Europe increase capacity	Monitor declared capacity for the major airports in Europe. If declared capacity is up by 25%, take D-action.	DA: Speed up expansions
Development of wind conditions due to climate change	Monitor the prevailing wind conditions throughout the year. If for 2 years in a row the number of days with cross-wind conditions exceeds 50, take D-action.	DA: Begin to implement the plan for the new runway

5.5 Step V: Implementation

In the implementation phase, the plan is implemented. This plan consists of the basic policy specified in Step II, the actions specified in Table 2 and Table 3, and the monitoring system specified in Table 4. Note that the new runway being planned in the basic policy is not built yet, but can be built when necessary in light of demand increases or capacity increases at other major European airports. As such, it is a real option. The same is true of the new terminal. All the preparatory work should be started, including the clearing of the land, relocation of the current facilities on the location to other places, and putting in place the required utilities (e.g. electricity, sewers, water, space for a connection to the existing terminal, connections to the highway system and the rail system). Construction should begin if triggered by demand developments or capacity developments at other airports.

During the implementation phase, Schiphol monitors the development. Schiphol might experience faster growth than anticipated in the plan. The signposts might indicate that Schiphol is maintaining its position as a major airport for the Skyteam alliance and its partners; however, the boundaries set for safety, the environment, and quality of life, and spatial integration with its surroundings might be violated. Construction of the new terminal can start. In addition, actions need to be taken to defend the policy with respect to the negative external effects. The noise insulation program can be expanded and more investment can be made in branding and marketing that aim at explaining the policy. If these actions prove to be insufficient, the noise insulation program can be expanded, Schiphol should start to buy out residents that are heavily affected by noise, and increase landing fees for environmentally unfriendly planes. If this still is insufficient, Schiphol should consider limiting the number of available slots, especially during the night and edges of the night. If these actions are still insufficient, either because demand grows very fast or because the environmental impact grows too fast, the policy should be reassessed. If this option is chosen, the decisionmakers would reiterate through the adaptive policymaking steps in order to develop a new (adaptive) policy.

6 Discussions

The design of AASP as outlined in this paper was motivated by the observation that it was possible to design an improved approach for ASP by combining ideas from APM, DSP, and FSP. The combined design draws on the relative strengths of the different approaches. Compared to APM, the main improvement is that AASP explicitly considers opportunities and also includes pro-active actions (i.e. shaping actions). Compared to FSP, AASP provides a systemic framework in which the many ideas (e.g. pro-activeness, opportunities, robustness, contingency planning) are integrated in a coherent stepwise approach. Compared to DSP, AASP contains many more ways to handle uncertainty in addition to real options. We, therefore, conclude that AASP is indeed an improvement over the three separate approaches. Subsequent research should therefore try to further develop and improve upon AASP. Below we outline some questions and issues that we think are of key relevance.

In Section 0, we introduced criteria that alternatives to AMP should at least meet in order to be considered a possible viable alternative. How does the approach outlined in this paper hold up to these criteria? First, the planning approach should consider many different types of uncertainties, in addition to demand uncertainties. As is shown by the case application, other uncertainties, such as uncertainty about future climate change and its impact on wind regimes, can be considered. There is no reason why the approach should be restricted to demand uncertainties only. Therefore, we conclude that AASP meets this first criterion. The second criterion is that the planning approach should consider many different plausible futures. As can be seen in the case, the approach allows for the consideration of different futures through the identification of a wide range of vulnerabilities. The third criterion is that the resulting plan should be robust across the different futures. At this time, we have insufficient tools to formally assess the robustness of the plan outlined above. However, given that the plan contains hedging and mitigating actions, it is plausible to assume that the plan is reasonably robust. The final criterion is that the resulting plan should be flexible. Flexibility of the plan is guaranteed via the monitoring system and its associated actions. For example, the plan allows for using Lelystad airport in the future, but it does not determine it. There is, thus, flexibility. In light of this, we conclude that the outlined approach does meet the four criteria outlined in Section 0. However, a more thorough assessment of the efficacy of the approach is needed.

New infrastructure planning approaches for handling the full range of uncertainties have seen limited application (Hansman et al., 2006). One reason for this is that the validity and efficacy of these new planning approaches has not been explored in depth (Hansman et al., 2006). There is currently no best practice for evaluating the efficacy of new planning approaches (Dewar et al., 1993; Hansman et al., 2006). In establishing the efficacy of new infrastructure planning approaches one faces a methodological problem for "nothing done in the short term can 'prove' the efficacy of a planning methodology; nor can the monitoring, over time, of a single instance of a plan generated by that methodology, unless there is a competing parallel plan." (Dewar et al., 1993). However, Frey and Dym (2006), suggest that by drawing an analogy with the evaluation and testing of new medicine, a methodology can be developed. For testing new infrastructure planning approaches, this analogy implies that evidence can be gathered through a variety of methods, including simulation gaming, computational experiments using exploratory modeling and analysis (Bankes, 1993), and face validation with experts (Kwakkel et al., 2009). Currently, we are working along these lines to assess the efficacy of the approach outlined in this paper in more detail.

A possible objection to adaptive planning in general is that it is too costly. For example, an airport cannot afford to buy up pieces of land without knowing whether they will use the land. However, this objection overlooks an important issue. Namely, the fact that the costs associated with the possibility to adapt is a form of insurance. That is, one pays a price in order to prevent larger costs in the future. So, in the case of the airport, the costs associated with not being able to build an additional runway will be extremely high if the airport runs into capacity limitations. The price that one is willing to pay for such insurance will have to be determined on a case by case basis. However, in most cases the cost can be rather low. As for example, instead of buying the land, a spatial land use reservation can be sufficient in case of the airport. Such a land use reservation will prevent the ground from being developed in a way that will prevent future use for a runway, without the airport currently having to buy the land.

There are two other open issues with AASP. First, long-term airport development is embedded in a lengthy policymaking process with many actors. Reaching decisions in such a network of actors can be very difficult. There are, therefore, strong incentives for creating a package deal that addresses many diverse issues related to the long-term development of an airport. The actors might very well prefer to reach a decision with apparently clear consequences instead of an adaptive decision, the effect of which will depend on how the external world develops. For example, airport planners might prefer to come to an agreement to start building a new runway now, rather than agreeing that a new runway can be built five years from now if certain levels of demand are reached. Second, since there are many actors involved, even if one succeeds in developing and agreeing on an adaptive policy, there is no guarantee that in the future the actors will live up to the current agreement. For example, future changes in the government can render current decisions superfluous. This is exemplified by the decision of the newly-elected government of the Netherlands to cancel the privatization of Schiphol in 2007. It might be possible to further develop the adaptive approach to incorporate these two open issues into the planning process.

7 Conclusions

The current dominant approach to the long-term development of an airport is AMP. In AMP, only demand uncertainties are taken into account. Demand uncertainties are treated via aviation demand forecasting. The final product of AMP, the Master Plan, is a static blueprint that will determine the future development of the airport. In general, this approach has not been very successful, mainly due to the many uncertainties airports face. Nowadays, airports operate in an increasingly uncertain context, rendering AMP even less appropriate.

Current research into strategic planning suggests that, in light of many uncertainties, planners should strive for flexibility or adaptability. Instead of trying to predict what will happen, which is impossible in light of these uncertainties, this research has focused on planning approaches that allow implementation to begin prior to the resolution of all the major uncertainties. Over time, the policy can be adapted as new information becomes available. Adaptation is made an explicit element of the policy development. With respect to the long-term development of airports, three different adaptive approaches have been proposed in the literature. Each of these three approaches emphasizes a different aspect of adaptive planning. DSP emphasizes real options, APM provides a detailed framework for the development of adaptive plans, and FSP covers a broad spectrum of planning concepts that together result in a thorough treatment of the many and diverse uncertainties airports face. The fact that each of these approaches emphasizes a different aspect of adaptive planning also suggests that they can be integrated into a single adaptive airport strategic planning approach.

We chose to use APM as our starting point and extended it to incorporate pro-active actions that aim at seizing opportunities and attempting to shape the external forces. The resulting approach is labeled Adaptive Airport Strategic Planning. It is a stepwise approach. First, similar to AMP, objectives, constraints, and available options are identified. Next, a basic plan is drafted and the conditions for its success are enumerated. Third, the basic plan is examined to reveal its vulnerabilities and opportunities. Where possible, actions that can be taken now to protect the plan against vulnerabilities are added to the plan. Similarly, actions aimed at seizing the available opportunities, thus enhancing the performance of the basic plan, are also added to the plan. For the remaining vulnerabilities, a monitoring system, triggers, and responsive actions are designed. The resulting plan consists of a set of actions that will be taken directly, and an adaptive part that consists of the planned adaptations and a monitoring system that will trigger the planned adaptations. The resulting approach was illustrated using the current debate about the long-term development of Schiphol as a starting point.

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