Transportation Planning and Technology

Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/gtpt20

Decision Support for Airport Strategic Planning

Roland A. A. Wijnen, Warren E. Walker & Jan H. Kwakkel

a Delft University of Technology, Faculty of Aerospace Engineering, Delft, The Netherlands
b Delft University of Technology, Faculty of Technology, Policy and Management, Delft, The Netherlands


To cite this article: Roland A. A. Wijnen, Warren E. Walker & Jan H. Kwakkel (2008): Decision Support for Airport Strategic Planning, Transportation Planning and Technology, 31:1, 11-34

To link to this article: http://dx.doi.org/10.1080/03081060701835670

PLEASE SCROLL DOWN FOR ARTICLE

Full terms and conditions of use: http://www.tandfonline.com/page/terms-and-conditions

This article may be used for research, teaching, and private study purposes. Any substantial or systematic reproduction, redistribution, reselling, loan, sub-licensing, systematic supply, or distribution in any form to anyone is expressly forbidden.

The publisher does not give any warranty express or implied or make any representation that the contents will be complete or accurate or up to date. The accuracy of any instructions, formulae, and drug doses should be independently verified with primary sources. The publisher shall not be liable for any loss, actions, claims, proceedings, demand, or costs or damages
whatsoever or howsoever caused arising directly or indirectly in connection with or arising out of the use of this material.
ARTICLE

Decision Support for Airport Strategic Planning

ROLAND A. A. WIJNEN*, WARREN E. WALKER** & JAN H. KWAKKEL**

*Faculty of Aerospace Engineering, Delft University of Technology, Delft, The Netherlands & **Faculty of Technology, Policy and Management, Delft University of Technology, Delft, The Netherlands

(Received 31 August 2007; Revised 8 November 2007; In final form 29 November 2007)

ABSTRACT Master Planning is currently the dominant approach to airport strategic planning. However, history shows that this approach can often result in costly mistakes. Because there are many stakeholders with conflicting objectives, deep uncertainty about the future, and many potential strategies, planners often narrow their scope by using a single forecast for the future, leaving out alternative strategies, and excluding stakeholders, resulting in a Master Plan that quickly becomes obsolete and may be opposed by some stakeholders.

What is needed is a flexible, integrated approach that enables collaboration among stakeholders. Such an approach can be facilitated using a Decision Support System (DSS) that provides a way for decisionmakers and stakeholders to evaluate alternative strategies quickly and easily with respect to their outcomes of interest. We present the conceptual design for a DSS called HARMOS, showing how it meets the high-level requirements for airport strategic planning while addressing the problems associated with Master Planning.

KEY WORDS: Airport strategic planning; Master Planning; Decision Support System; policy analysis; HARMOS

Correspondence Address: Roland A. A. Wijnen. Faculty of Technology, Policy and Management, Delft University of Technology, P.O. Box 5015, 2600 GA Delft, The Netherlands. Email: R.A.A. Wijnen@tudelft.nl

ISSN 0308-1060 print: ISSN 1029-0354 online © 2008 Taylor & Francis
DOI: 10.1080/03081060701835670
Introduction

The history of powered flight over the past 100 years has been one of constant change: it took off after decades of empirical research, continued to be developed by trial and error, was accelerated by World War I, became more and more a means of mass transportation after World War II, and now has become a force that moves the planet. Airports are the elements of the aviation system that provide the ground infrastructure that is required for enabling organized flight across the globe. Today, the aviation industry is in the midst of rapid change, stimulated by both internal forces (e.g. airline mergers and low cost carriers) and external forces (e.g. terrorist threats and environmental regulations). Airports have been and are constantly affected by these changes, which force them to adapt accordingly. Looking at airport developments in retrospect shows that adapting is not always easy. Privatization and liberalization put pressure on airport decisionmaking: opportunities have to be seized and threats dealt with quicker than ever before. Merely trying to keep pace with growing travel demand is not enough; airport planners and decisionmakers also have to provide solutions for mitigating the adverse effects of growth that are satisfactory to their stakeholders (communities, air navigation service providers (ANSPs), airlines, governments, etc.). Doing this successfully is difficult, given the growing opposition to airport expansion plans around the world.

Currently, the airport Master Plan is the core artifact of airport strategic planning. Master Planning is a recommended practice by the International Civil Aviation Organization and required by the Federal Aviation Administration in the United States (ICAO, 2004; FAA, 2005). Most airports in the world, therefore, periodically create one. Although airport operators have increasingly involved a variety of stakeholders in their Master Planning and decisionmaking processes, this has generally not led to improved decisionmaking with respect to future development. In addition, most Master Planning studies take a very long time to complete and run the risk of becoming obsolete by the time they are completed because of new conditions that had not been taken into account. Just recently, construction began on the first project defined in the Master Plan for Los Angeles International Airport, after 10 years of analysis, public discussion, and negotiation (LAWA, 2006). During the planning study, the plan underwent major transformations and revisions in order to reflect the changing environment (LAWA, 2005). Other cases show that implementation of a plan is hampered by the fact that some stakeholders’ perspectives have been misunderstood or their objectives or concerns had not been taken into account adequately. Two examples of plans that faced major opposition and
implementation delay are the plans for the new runways at Boston Logan Airport (proposed in 1973 with the decision to build in 2006) and the so-called ‘Polderbaan’ at Amsterdam Airport Schiphol (proposed in the 1970s and opened in 2003).

A primary reason for the lack of success of current approaches to planning is the complexity and uncertainty that planners and decision-makers have to deal with. Not only are there many stakeholders with different objectives and concerns that need to be considered, but the airport system itself is also complex. It consists of many components that have to fit together so that both passengers and aircraft are processed efficiently and safely; at the same time, the adverse effects (e.g. noise, air pollution, road congestion) of these passenger and aircraft flows have to be considered as well. The context in which airports operate is subject to changes in terms of aviation demand, technological developments, demography, and regulations; the uncertainties associated with these changes need to be taken into account as well. Usually, there are large numbers of possible changes that can be made to an airport system, each having different effects on the airport’s performance (e.g. delay, environmental impacts, profits). Because the effect of system changes on airport performance are interdependent and affect the objectives of the stakeholders differently, they need to be considered in an integrated way – as complete packages, not as separate, independent changes. It is also essential to consider the changes and their effects for different plausible futures.

The Master Planning effort itself involves the mobilization of an array of disparate resources (internal staff, consultants, stakeholder representatives) and the assembling of a great deal of data and information. Conducting the quantitative part of the analysis involves selecting the appropriate tools and processing their results. The inputs and the results need to be consistent and valid, which usually requires a significant effort. And all of these activities have to be repeated when a new problem has to be analyzed at some time in the future. Currently, there is not enough time or resources to perform the analysis in a quality way – to assemble the data, prepare the analytical tools, and explore future problems, issues, and bottlenecks in the airport system and their potential solutions to the satisfaction of all stakeholders.

Fortunately, the conditions outlined above provide an ideal setting for the application of a Decision Support System (DSS) that would support a multi-stakeholder approach for addressing the wide range of airport strategic planning problems and would efficiently integrate the analytical and human resources within the airport operator’s organization. This paper provides the conceptual design for such a DSS as it emerged from the (iterative and incremental) software development
process that is ongoing to actually build the software (Wijnen, 2006). Additionally, our experience with previous work on tools for airport strategic planning has been used as input (Walker et al., 2003; Visser et al., 2003). In what follows we use Turban’s (1995) definition of a DSS as an interactive, flexible, and adaptable computer-based information system, developed for supporting the solution of a non-structured management problem for improved decision making.

The remainder of this paper is organized as follows. The current airport strategic planning process is examined in more detail with the purpose of identifying the people involved, the activities being employed, and the problems with this approach. Based on an understanding of the current strategic planning process, the role and functionality of a DSS to support the process is shown to be an approach that solves these problems. Finally, the key principles for designing such a DSS and the resulting conceptual design are presented.

Current Airport Strategic Planning

We provide a simplified, conceptual description of how current airport strategic planning is carried out in order to identify in more detail its problems and their causes. We define strategic planning to be the managerial activity that produces fundamental decisions and actions that shape and guide what the organization is, what it does, and why it does it (Bryson, 2004). This implies that strategic planning can be carried out through different approaches. In the case of airport strategic planning, Master Planning is currently the dominant approach, although there are alternatives (de Neufville, 1991; de Neufville & Odoni, 2003). Our description assumes that the airport operator is ultimately responsible for airport planning and coordinates the planning effort. In reality, airport planning consultants might be heavily involved and even responsible for creating the final plan; the relationship between the airport operator and the consultants depends on the local setting, size of the airport operator’s organization, and regulatory framework. Figure 1 provides a conceptual map of current airport strategic planning. It is meant to provide a generic overview of airport strategic planning and is not meant to represent any specific airport’s approach. The map has been determined empirically and shows that many resources are involved, both inside as well as outside the organization: a lot of data are involved, requiring a significant number of people, possibly using tools, to turn the data into information relevant for decisionmaking.
People

The people involved in airport strategic planning can be divided into two groups – those inside the airport operator’s organization and those outside the organization. People inside the airport operator’s organization are the ones that are directly involved in the strategic planning process; they carry out different types of activities to support the creation of a strategic plan that supports the management’s vision. People outside the airport operator’s organization are typically associated with organizations or groups that have a stake in the airport’s development, which we collectively call the airport’s stakeholders. These stakeholders (e.g. airlines, ANSPs, aviation authorities, community groups) have conflicting goals and objectives with respect to the airport’s development. The way the stakeholders are involved depends on the local setting, and their role may vary from merely making their views known to being official partners in making agreements about the actual airport development and operations. Stakeholders have significant power (e.g. public campaigns, lobbying, appealing to court) to influence an airport operator’s planning process and will do so whenever they think that their objectives and goals are not being sufficiently taken into account.

Data and Information

Creating an effective strategic plan requires consistent data and information about a wide range of aspects. The types of data and information are: (i) the business goals, usually implicitly contained in an organization’s vision and further specified (qualitatively or quantitatively) by the airport’s management team; (ii) the future
context for the airport’s operation in terms of economic, technological, regulatory, and demographic developments; (iii) the airport system and its environment, modeled at the appropriate level of detail; (iv) system changes (structural, operational, and/or managerial) due to strategies; and (v) quantitative airport performance information for the given future context and strategies. With respect to airport performance, information at different levels of detail is required concerning capacity and delay, and environmental impacts (noise, emissions, and third-party risk). Nowadays, the financial implications of a plan are also important. Often, outside consultants are contracted to provide information about some or all of these airport performance aspects.

**Tools**

Much of the data and information are generated using analytical tools, typically related to capacity and delay, environmental impacts (noise, emissions, and third-party risk), and financial performance. In most cases, this data and information are not generated in a consistent, integrated way. Usually, only a single aspect of the airport’s operation (e.g. its capacity and delay or noise or emissions) is evaluated at a single time. Only if there is a problem to be expected with another aspect, additional analyses are conducted. The reason for this is that different aspects are usually assessed by different experts, who are not all from the same organization. First, an expert needs to get appropriate data and information. Next, the data and information have to be processed in order to be used as input to the tools being used. Then the experts execute the appropriate runs with their tools, post-process the outcomes, and return the results to an advisor, who either uses it in a report or directly communicates it to the decisionmaker. If one of them is not satisfied with the results, or needs an assessment of another situation, the whole process is repeated. Airport staff may have automated some of the pre- and post-processing tasks, but there is still a risk of data redundancy and conflicting assumptions.

**Problems with Current Airport Strategic Planning**

Getting all the relevant stakeholders directly involved in the airport operator’s strategic planning process is one of the general problems. The recent update of the FAA’s advisory circular for Master Planning was specifically rewritten to address this issue (FAA, 2005). Other, more specific problems are:
• **Too few scenarios are considered.** Because of a lack of resources, planners analyze only a limited number of futures (usually only one). As stated by Ascher (1978) and repeated by many others (e.g. de Neufville & Odoni, 2003): "the forecast is always wrong", which means that the traditional ‘predict and act’ approach is likely to produce a poorly performing plan.

• **Too few alternatives are analyzed.** The problems related to long-term airport development are not exhaustively explored with respect to all of the different aspects and stakeholder perspectives. Only a short list of alternatives is usually considered and combined in a single strategy, based on what is known to have more or less worked in the past. This eventually delays or halts implementation, because of the resulting lack of stakeholder and societal support for the proposed plan.

• **Resources are used inefficiently.** Often, people involved in estimating different outcomes of interest (e.g. noise, delays, finances) work on different parts of the analysis, each using different models/tools, assumptions, and data. This makes it difficult to produce a consistent, integrated set of results that can be used to support a specific plan. An integral view on the airport's performance can only be produced (if at all) by manually collecting, combining, and post-processing the individual results, which is usually not done.

• **Collaboration among stakeholders is problematic.** In addition to inconsistencies in data, assumptions, models, and results, the current approach does not facilitate easy and comprehensive collaboration among the stakeholders, resulting in excluding some of them altogether, or involving them too late. History shows that this causes serious problems when an airport operator tries to implement its Master Plan. Numerous examples, some of them very successful, are available of legal actions from the excluded stakeholders to prevent a plan from becoming reality (Caves & Gosling, 1999; Dempsey, 1999).

• **There are often conflicts among the various stakeholders.** Stakeholders are likely to argue about results, assumptions, and the methodologies that were used, either because they were not involved or do not understand each other (or both).

A major fundamental cause of these problems is a dispersion of data, tools, information, and knowledge within the organization of the airport operator and those of its stakeholders. Resources cannot be easily integrated, consolidated, and focused on producing an effective plan. The result is an inefficient strategic planning process that is not able to support the creation of a transparent plan, based on a thorough
understanding of both the airport system and plausible future contexts, that is acceptable to all stakeholders.

In principle, such problems could be solved through the use of a DSS. However, the context in which decision support is to be realized, which has been described above for airport strategic planning, has often been forgotten in DSS development projects (Dodson, Arnott & Pervan, 2006; Brown, 2006). As a result, it is not clear what the DSS being designed is trying to support and what functionality it should provide. Hence, after the DSS is developed, it is not used in practical applications (Poon & Wagner, 2001; Briggs & Arnott, 2004; Arnott & Pervan, 2005).

**Design Principles for a DSS for Airport Strategic Planning**

The previous discussion makes it clear that there is much room for improvements in airport strategic planning. On the one hand, planners need to improve their understanding of the system and its problems, the airport’s future performance given deep uncertainty about the future, and the strategies for addressing these problems. On the other hand, airport decisionmakers need to understand how their business decisions affect their goals and those of their stakeholders such that they are able to define a vision that satisfies both.

We propose that any approach to airport strategic planning should address both issues simultaneously, because we believe that only a holistic approach can meet the decision support needs of the airport of the future. This proposition is based on the observation that the success of an organization is determined by its ability to have people working together both within the organization as well as with its stakeholders. One of the prerequisites of working together is the ability to share information effectively. Just sharing information is, however, not enough; information should be shared in such a way that an organization and its stakeholders gain an understanding of each other’s perspectives and objectives. Only when there is a mutual understanding is it possible to look for solutions that are satisfactory to all parties involved (see the left side of Figure 2).

As noted above, the current airport strategic planning and decision-making process includes many common, repetitive activities with data and tools dispersed throughout and outside the organization. It would be sensible to incorporate these into a DSS. By doing so, decision-makers, decision advisors, and domain experts can work more efficiently and effectively in analyzing problems, thereby unlocking their creative powers, rather than spending large amounts of time on activities that a DSS can do faster and better. The DSS will also integrate and institutionalize the planning process, data and
information, and tools within the organization so that a new strategic problem does not require starting from scratch every time it arises.

Our proposed solution, which we call the HARMOS DSS, enables an airport operator to deploy its resources—people (knowledge), data and information, and tools—more efficiently, resulting in an improved understanding of the airport system, its problems and potential solutions, while explicitly facilitating the involvement of stakeholders in the planning process. As a result, airport staff (e.g., management, planners, and experts) and airport stakeholders can work together on solving their problems and improving mutual understanding, so that a shared vision of the future airport can be created. The two key design principles underlying HARMOS are: (1) the adoption of the policy analysis approach; and (2) the integration of resources. We discuss these design principles below.

The Policy Analysis Approach

Policy analysis (Miser & Quade, 1985) is a systematic, well-defined, complete, and comprehensive approach for problem analysis and decision making that evolved out of operations research and systems analysis (Davis et al., 2005). It is widely accepted for analyzing a diversity of problems, and generic enough for addressing the wide range of airport planning problems. Policy analysis explicitly recognizes that problems caused by systems affect many stakeholders, and hence finding solutions needs to be done by involving those stakeholders (van de Riet, 2003).

Figure 3 presents the approach for structuring a policy analysis study statically (framework) and dynamically (process), based on Walker (2000). The framework is an integral system description of a policy
field; at its heart is a description of the system domain in the form of a system model that clarifies the system by: (1) defining its boundaries; and (2) defining its structure—the elements, and the links, flows, and relationships among them. Two sets of forces act on the system: external factors outside the control, and strategies under the control of the actors in the decisionmaking domain. Both sets of forces affect the structure of the system and, hence, the outcomes of interest to the decisionmakers and stakeholders.

The process generally involves performing the same set of logical steps (Walker, 2000). These steps are not necessarily performed in the same order and there is usually feedback among the steps. More general information about the individual steps in the process is described in detail by Miser and Quade (1985) and by Quade (1989). The steps are:

- **Step 1: Identify the Problem.** Identify the planning problem, clarify constraints on possible strategies, identify the airport stakeholders, and discover the major operative factors.
- **Step 2: Identify Objectives.** Identify business objectives (i.e. from the airport operator) and the objectives of other stakeholders so that later it can be determined if: (1) a strategy solves the problem identified or seizes the opportunity; and (2) how a strategy affects the various stakeholders.
- **Step 3: Decide on Criteria.** Identify the consequences of a strategy that can be estimated (quantitatively or qualitatively) and that are directly related to the objectives. It is essential to have an integral
view of the airport’s future performance so that bottlenecks and adverse effects of a specific strategy on the airport’s overall performance can be correctly identified.

- **Step 4: Develop Scenarios.** Define the future contexts within which the problems are to be analyzed and the strategies will have to function. In this step, several plausible scenarios are developed. A scenario is a specification of the external factors influencing the system, including their effects on the structure or operations of the system over a specified planning period. Scenarios are not complete descriptions of the future; they include only those aspects that might strongly affect the outcomes of interest. It is important to include enough scenarios to cover a broad range of uncertainties. Omitting an uncertainty from the scenarios implies that the effects of that uncertainty are not important, since they will not be examined in the analysis.

- **Step 5: Select Alternative Strategies.** It is important to include as many strategies as stand any chance of being worthwhile (‘think the unthinkable’). If a strategy is not included in this step, it will never be examined, so there is no way of knowing how good it may be. The current strategy (*business as usual*) should be included too (often referred to as the ‘base case’), in order to determine how much of an improvement can be expected from the other strategies.

- **Step 6: Analyze Strategies.** Determine the consequences that are likely to follow if the strategy is actually implemented in each of the scenarios, where the consequences are measured in terms of the criteria chosen in Step 3.

- **Step 7: Compare Strategies.** Examine the strategies in terms of their estimated outcomes for each of the scenarios, making tradeoffs among them, and choosing a preferred strategy (or combination of strategies), which is robust across the future contexts. If none of the strategies examined so far are good enough to be implemented (or if new aspects of the problem have been found, or the analysis has led to new strategies), return to Step 5.

The policy analysis approach has been applied to many problems, both in the private and public domain. However, to our knowledge it has never been used as the basis for DSS design, since most policy analysis studies are designed to solve a single, unique problem once. Airport strategic planning should be a continual, repetitive process. The nature of airport strategic planning (a multi-stakeholder setting and a complex system under study) makes a way to structure the problem and a clear problem solving process an absolute must. An airport operator’s organization and its stakeholders can be supported in their strategic
planning by using a structured, comprehensive framework. Policy analysis provides such a framework.

The Integration of Resources

As already pointed out, one of the fundamental causes of problems in current airport strategic planning is a dispersion of data, tools, information, and knowledge within the organization of the airport operator and its stakeholders. An integrative approach toward the deployment of people, data/information, and tools is needed to address these problems. We discuss the integration of these three types of resources in the following three sections.

People. Many people are involved in airport strategic planning, both from inside and outside the organization (i.e. representatives from the stakeholders). Each of them plays a different role and conducts specific tasks, either throughout the entire duration of the planning study or at specific times. In order to achieve the integration of resources, it is necessary to identify the different roles of these actors. As pointed out, in order to be successful, airport strategic planning should be a collective effort of both the people within the airport operator’s organization and its stakeholders. Therefore, both groups should be able to use the DSS.

A further division can be made with regard to the roles with respect to the strategic planning effort. Conceptually, those roles are shown in Figure 4, including the main sources of information that people with these roles use or have available. There are three major roles in the

![Figure 4. Roles of the people involved, their information needs and sources](image-url)
planning process, which are performed by one or more persons, depending on the size of the airport operator’s organization:

- **Decisionmakers.** The persons that have the decision power to develop and implement strategies for the airport’s development, operation, and management. Strategies are developed such that they meet the business goals associated with the vision about the airport of the future. Decisionmakers usually do not make direct use of (analytical) computer tools. The sources these people use are very diverse (e.g. newspapers, meetings with airport staff and stakeholders, and their intuition) and include their own mental models and input from their advisors.

- **Decision Advisors.** The persons that advise the people that make the actual decisions. Decision advisors explore the strategies that could be implemented for meeting the goals set by the decisionmakers. In order to accomplish this task, they hire external consultants, use in-house computer tools, and consult domain experts.

- **Domain Experts.** The persons that have specific knowledge of the airport system (e.g. of the airside, landside, ground access infrastructure) and its operation. The domain expert uses various tools to provide quantitative information about the (future) airport performance (e.g. capacity and delay, environmental impacts, and financial results).

The realization of the DSS design that services the different needs of people with each of these roles is discussed in section ‘Integrating People’.

**Data and information.** Integrating data and information helps reduce the coordination effort required for making sure that the decision advisors, domain experts, and external consultants use a consistent set of data and assumptions. It also makes data, such as current information about the airport infrastructure and operation, airlines and their flight schedules and networks, aircraft and their noise and emissions characteristics, and demographics (e.g. population densities, dwellings, housing projects) available for easy retrieval, analysis, and reuse. Moreover, it makes sure that the information is valid and consistent (and remains so) and that it can be easily shared. The aforementioned policy analysis framework can help in structuring the data in a clear manner (discussed in section ‘Integrating Data and Information’).

**Tools.** The dispersion of tools both within and across organizations leads to inconsistencies between assumptions and input data used for setting up the tools for airport performance analysis. A tool, such as the Integrated Noise Model (INM), is frequently used for land-use
compatibility planning (Gulding et al., 1999; FAA, 1983) and for determining the effect of forecast airport operations within airport Master Planning studies. In order to use INM, an expert needs to first create and set up an INM study, which means selecting, checking, and setting up the INM default data for the specific airport under consideration. Next, an expert needs to provide input data about the airport infrastructure (runways and tracks) and the airport operation, prepare noise metrics and other computational settings, run the computations, and finally interpret the results. If another situation needs to be assessed, this process or parts of it need to be repeated. Because of this effort, detailed environmental analysis (i.e. the analysis of noise and emissions) is usually postponed until it is more or less clear which infrastructural developments are to be included in the plan. However if the use of all the tools for all the analyses were coordinated by a single DSS, an integral assessment of all relevant outcomes of a strategy could be carried out at the same time. These facts, and the need for consistent assumptions across all of the analyses, make it clear that it would be more efficient and effective if all of the tools were controlled centrally, as we will discuss in section ‘Integrating Tools’.

Conceptual Design of the HARMOS DSS

The analysis of the current airport strategic planning approach shown in Figure 1 revealed that:

1. many people with different roles are involved, who conduct fundamentally different activities;
2. a huge amount of data and information is needed and generated; and
3. different tools need to be deployed and used.

Based on these observations, we defined three categories of resources: people, data and information, and tools. A concrete planning study involves specific resources from the airport operator and from its stakeholders. Currently, those resources are not embedded in a unified structure, which makes it difficult to use them efficiently. Adopting the principles described in section ‘Design Principles for a DSS for Airport Strategic Planning’ and using them consistently results in the conceptual design of the HARMOS DSS as presented in Figure 5.

HARMOS has a layered design, with each layer partitioned into packages, each of which has a clear responsibility. Within the packages there is a further partitioning so that the design is truly modular, making the DSS easy to maintain, extend, and/or customize for a potential customer. The layers are:
Graphical User Interface (GUI): the interface between the DSS’ functionality and the users.

Domain: incorporates the core functionality for supporting the strategic planning effort.

Technical Services: incorporates lower-level, more generic services used by the higher-level layers.

The GUI is designed such that it meets the specific information and task requirements of the roles identified in Figure 4, but its components are not further discussed. The packages within the domain layer are:

- **Analysis Tool**
  - Capacity & Delay
  - Noise
  - Emissions
  - Third-Party Risk
  - Financial

- **System Model**
- **Scenario Generator**
- **Strategy Explorer**
- **Decision Explorer**
- **Performance Analysis**

- **GUI**
  - Disseminate and Share Information related to Decisionmaking
  - Explore Business as Usual and Strategies for Facing the Future
  - Prepare, Execute, and Evaluate Analysis.

- **Technical Services**
  - AVIATION
  - AIRPORT
  - STUDY
  - Miscellaneous Services
    - Import/Export
    - DB Interfaces

- **Existing Databases**

**Figure 5. The conceptual design of HARMOS**
Study and Case Management. Provides functionality for organizing the strategic planning effort.

Scenario Generator. Responsible for capturing data about the future developments of the external factors (one of the forces in the policy analysis framework, see also Figure 3), so that domain experts and decision advisors can create multiple scenarios representing a range of plausible futures. Those scenarios include future flight schedules in an Official Airline Guide (OAG) format, using current OAG data about scheduled airline operations as the starting point.

System Model Manager. Incorporates a generic system description, being the heart of the policy analysis framework (see also Figure 3), as discussed in much more detail in section ‘Integrating Data and Information’. The package provides functionality to create system models as a function of time within the planning period, including the effect of the forces (external factors and strategies) on the system. The package also provides functionality for retrieving, updating, and deleting specific system models.

Performance Analysis. Provides an interface between the problem and the tools; it is responsible for transferring the information from the problem context to the tool context (pre-processing), so that quantitative results about the airport’s performance can be generated (computations) and digested (post-processing) so that finally they can be evaluated by one of the DSS users. The tools are not incorporated into the DSS; instead the DSS calls upon some of the computational services of third-party tools through a so-called ‘adapter’.

Strategy Explorer. Provides the functionality for defining strategies, assessing their effect on the airport’s future performance, and comparing them (business as usual strategy with new strategies and one new strategy versus another).

Decision Explorer. Each of the strategies explored by the decision advisors will solve the future bottlenecks in a more or less satisfying manner, depending on the stakeholder that is considered. This package allows decision advisors to present the results of the strategy exploration to the decisionmakers from the perspectives of various stakeholders, so that they can discuss, negotiate, and decide upon a strategy (or combination of strategies) that is preferred for implementation. Obviously, the decisionmakers could also come up with new strategies that should be explored before coming to an agreement.

The technical services mainly provide functionality for disclosing data needed for setting up an airport planning study or permanently storing the user-generated information within an airport planning study. Three types of databases are incorporated:
• **Aviation.** Includes generic data, such as the world’s airline fleets, and aircraft characteristics (e.g. flight performance, noise, and emissions data).

• **Airport.** Includes airport specific data, such as traffic demand data (based on the OAG format and data), historic wind data, and data related to economic forecasts.

• **Study.** Includes data and information related to a specific planning study (e.g. the decisionmaking context, scenarios, and strategies).

Another package that is incorporated in this layer provides miscellaneous services, such as data import and export functionality and functionality to interface with existing databases within the airport operator’s organization.

**Integrating People**

The HARMOS GUI (the top layer in Figure 5) provides the interface between the DSS and its users, enabling them to interact with the DSS based on their role in the strategic planning effort. Their tasks are not independently executed anymore; they are interrelated, and connected within the workflow for problem solving that the HARMOS DSS provides. Through the GUI, the following functionality is provided for each role (note that these roles are adopted by people from the airport operator’s organization as well as by representatives of the airport’s stakeholders):

• **Decisionmakers** disseminate and share information related to decisionmaking. They compare the business as usual strategy with other strategies that have been explored so that they can discuss them with other stakeholders to find out which strategy is collectively preferred to be implemented.

• **Decision advisors** define and explore strategies for dealing with the future (either for solving problems or seizing opportunities). This task includes preparing scenarios resembling different futures, and analyzing the overall airport performance (airside and landside delays, environmental impacts, and profits or losses) for the business as usual strategy and any other proposed strategy (e.g. building a new runway, extension of the terminal, demand management).

• **Domain experts** prepare, execute, and evaluate quantitative analyses related to the airport’s performance in terms of capacity and delay, noise, emissions, third-party risk, and financial aspects.
Integrating Data and Information

As pointed out, a huge amount of data need to be processed iteratively and interactively by different people before the relevant information for decisionmaking becomes available. Currently, this is done using a bottom-up approach in which the decision advisors analyze and digest large amounts of data to obtain the required information. The HARMOS DSS uses a top-down approach, which starts from what needs to be known from the problem point of view. Based on this view, the context for problem analysis is determined, which in turn reveals the data and information needs. Using a top-down or problem-oriented approach, there is much more focus on what is really needed in terms of information, which makes data gathering and processing much more efficient.

Categorizing data as well as turning data into useful information follows naturally from adopting the policy analysis framework. Based on the framework (see Figure 3), we defined four categories of data: system, external factors, strategies, and outcomes of interest. Each of those categories has been modeled in a similar fashion, but only the static structure of the system category is described in detail.

The system category captures data to describe and model the system, but we also need to capture the nature of the elements and the relationships among the elements. At the top level, the system model consists of three subsystems – the airport, its (physical) environment, and other systems. The last is a collection of systems that an airport depends on, such as the Air Traffic Management (ATM) system or the road network outside the airport property. The reason that those are not separately included in the system model is because we do not need to describe them in detail for the purposes of airport strategic planning. Only the characteristics that directly affect the airport operation have to be included. The system model hierarchy is depicted in Figure 6, which shows some of the details of the runway system (one of the components of the airside subsystem of an airport). In this way, the real world is reflected quite naturally in the DSS, while at the same time providing a single and consistent data model of the relevant airport subsystems, taking into account their interrelationships.

The most important advantage of structuring data and information according to the policy analysis framework is that there are clear distinctions among data that are related to the system, the external factors, the strategies, and the outcomes of interest for the problem at hand. Tables 1 and 2 provide concrete examples for each of the four categories of data (but they are not intended to provide an exhaustive overview of the data that need to be collected for each category).
Integrating Tools

Table 2 presented a number of outcome indicators for each of the outcomes of interest (i.e. capacity and delay, noise, emissions, third-party risk, and financial). During the strategic planning process, these outcome indicators need to be quantified for various different situations so that they can be assessed by a domain expert and/or decision advisor. The outcome indicators need to be quantified for a specific period of interest (either a day or a year). For each period, the performance analysis package is used (see Figure 5) for the actual quantitative analysis. The performance analysis package pre-processes data, executes tools, and post-processes the generated results to draw meaning from them. The tool adapter mentioned before is the interface between the DSS and the tool, which is responsible for converting information from the problem context to the tool context, control the execution of the tool, and convert the tool results back to the problem context. Returning to the activity of conducting noise analysis with the INM as described in section ‘Tools’, the sequence of events based on the need of a decision advisor to assess the noise impact of a strategy is the following:

1. Specific outcome indicators (e.g. noise contours and areas, population counts) are selected through the GUI.
2. HARMOS checks whether all the input required to quantify the selected outcome indicators is available:
a. if all input is available, the decision advisor proceeds with Step 3;
b. if input is missing (e.g. census data, departure/arrival tracks), HARMOS notifies the user so that the appropriate data can be retrieved and added to the system model (probably with the help of domain experts).

3. The domain expert starts the noise analysis from the GUI, which in turn calls upon the performance analysis package for doing the work. The performance analysis package:
   a. automatically creates an INM study, retrieves the appropriate data from the system model, and converts that into specific input for INM (pre-processing);

Table 1. Organization of data according to the policy analysis framework: forces on the system

<table>
<thead>
<tr>
<th>External factors</th>
<th>Strategies</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Economy</strong></td>
<td></td>
</tr>
<tr>
<td>- Traffic demand and mix (regional jets, new large aircraft).</td>
<td></td>
</tr>
<tr>
<td>- Growth rates.</td>
<td></td>
</tr>
<tr>
<td>- Type of demand: business, leisure, transfer.</td>
<td></td>
</tr>
<tr>
<td>- Market share low cost carriers and other airlines.</td>
<td></td>
</tr>
<tr>
<td>- Aviation market conditions: deregulation, liberalization, globalization, competition, privatization.</td>
<td></td>
</tr>
<tr>
<td><strong>Technology</strong></td>
<td></td>
</tr>
<tr>
<td>- New modes of transport.</td>
<td></td>
</tr>
<tr>
<td>- Air Traffic Management.</td>
<td></td>
</tr>
<tr>
<td>- New aircraft designs.</td>
<td></td>
</tr>
<tr>
<td>- Noise reductions: engine &amp; airframe.</td>
<td></td>
</tr>
<tr>
<td>- Emission reductions.</td>
<td></td>
</tr>
<tr>
<td><strong>Regulation</strong></td>
<td></td>
</tr>
<tr>
<td>- Effect of noise levels on disturbance.</td>
<td></td>
</tr>
<tr>
<td>- Effect of pollutant emissions on public health.</td>
<td></td>
</tr>
<tr>
<td>- New government regulations.</td>
<td></td>
</tr>
<tr>
<td>- Slot allocation.</td>
<td></td>
</tr>
<tr>
<td><strong>Demographics</strong></td>
<td></td>
</tr>
<tr>
<td>- Population growth.</td>
<td></td>
</tr>
<tr>
<td>- Effect of noise impact and third-party risk on population (distribution) and housing developments.</td>
<td></td>
</tr>
<tr>
<td><strong>Strategies to improve airside capacity</strong></td>
<td></td>
</tr>
<tr>
<td>- Additional infrastructure: runways, taxiway system design.</td>
<td></td>
</tr>
<tr>
<td>- New operational concepts and technology.</td>
<td></td>
</tr>
<tr>
<td>- Change in aircraft mix.</td>
<td></td>
</tr>
<tr>
<td><strong>Strategies to reduce environmental impact</strong></td>
<td></td>
</tr>
<tr>
<td>- Noise abatement procedures (NAP).</td>
<td></td>
</tr>
<tr>
<td>- Reorganizing departure (SID) and arrival (STAR) routes.</td>
<td></td>
</tr>
<tr>
<td>- Ban or curfews on noisy aircraft.</td>
<td></td>
</tr>
<tr>
<td>- Single engine taxiing.</td>
<td></td>
</tr>
<tr>
<td>- Insulation of houses.</td>
<td></td>
</tr>
<tr>
<td>- Runway allocation strategies.</td>
<td></td>
</tr>
<tr>
<td><strong>Strategies to improve landside capacity</strong></td>
<td></td>
</tr>
<tr>
<td>- New check-in procedures.</td>
<td></td>
</tr>
<tr>
<td>- Additional landside infrastructure: new pier, new terminal.</td>
<td></td>
</tr>
<tr>
<td>- Different security procedures.</td>
<td></td>
</tr>
<tr>
<td><strong>Strategies for increasing revenues</strong></td>
<td></td>
</tr>
<tr>
<td>- Real estate developments.</td>
<td></td>
</tr>
<tr>
<td>- Expanding shopping areas.</td>
<td></td>
</tr>
<tr>
<td>- Parking services.</td>
<td></td>
</tr>
<tr>
<td>- Meeting facilities (golf course, conference centre).</td>
<td></td>
</tr>
</tbody>
</table>
b. starts INM, sends it a message to start the actual computations, and shuts it down when it is finished (tool execution and control);

c. retrieves the results from INM, and converts those results into the appropriate format for presentation within the problem context. When noise contours and population counts have been requested, the contours are plotted on a background map, and calculations are made to determine the number of people inside those contours (post-processing).

Along the same lines, the HARMOS DSS provides functionality for obtaining information about any other performance aspect (i.e. capacity and delay, emissions, third-part risk, and financial) given any particular situation in the decisionmaking context.

Conclusions

Current airport strategic planning is primarily based on Master Planning, which is problematic because, in general, in Master Planning
uncertainties about the future are not properly addressed, and involvement of stakeholders is inadequate. We have argued that, in today’s rapidly changing world, there is a continuous need for airport operators to update their plans, which is why we propose that the practice of Master Planning should adopt a flexible and integrated approach to strategic planning. This approach should acknowledge the fact that the future is uncertain and is about exploring many different strategies that may contribute to realizing a vision about the airport of the future. It does not necessarily produce a single static plan. By adopting a flexible and integrated approach to strategic planning, airport management is able to change its strategy as the future unfolds. However, involvement of the entire organization and all airport stakeholders is essential for actually being able to implement new strategies. Current airport planning practice is already a cumbersome and resource intensive process, so transitioning to a planning process that allows continuous updating of plans will be difficult without appropriate support. We, therefore, proposed a DSS to support airport strategic planning. The high-level design principles for such a DSS were presented and we showed how those principles (the policy analysis approach and integration of resources) were adopted for the conceptual design of the HARMOS DSS. The resulting conceptual design shows great promise in enabling airport staff and stakeholders to be more efficient and effective in exploring strategies for achieving their visions of the airport of the future. The HARMOS DSS integrates and institutionalizes the planning process, data and information, and tools in a multi-stakeholder context, so that successive strategic planning studies can easily make use of the data and information, and tools, and results from previous studies, thereby reducing the time and resources needed to carry out a new planning study.

Our general conclusions are:

- Analyzing the current strategic planning approach is essential for identifying the problem that is to be solved by a DSS, and identifying the users, and their high-level needs.
- The conceptual design of HARMOS supports airport strategic planning through all levels – i.e. from the expert in the organization to the final decisionmaker.
- The policy analysis approach provides a well-defined and systematic framework for exploring airport planning problems within the context of an uncertain future. Adopting the policy analysis approach as the foundation for the design of the DSS is an effective way to deal with system complexity and uncertainty.
- The strategic planning process becomes institutionalized through the HARMOS DSS instead of remaining an ad hoc process. This enables
an organization to better respond to change with respect to the
future that unfolds, the problems it brings, and solutions that can be
provided. With the HARMOS DSS, solutions to new problems might
even have been explored before, so that their results can be retrieved
and the analyses do not have to be redone entirely from scratch.
• By using the HARMOS DSS, an organization can be provided with
an effective learning capability and memory function, which initially
helps to improve the strategic planning process and eventually
enables strategic thinking across all levels of the organization.
• Using the HARMOS DSS, the focus of a planning effort shifts from
rather technically oriented Master Planning to a stakeholder-
oriented approach to strategic planning, in which the airport
operator and stakeholders explore future problems and strategies
for addressing them together, resulting in a flexible and adaptable
strategic plan, instead of a fixed and rigid Master Plan.

The conceptual design outlined in this paper has already been
implemented in prototype software. Our next step is to customize
and test the DSS within the organizational context of an airport
operator in Europe.

References

Ascher, W. (1978) Forecasting: An Appraisal for Policy-makers and Planners (Baltimore, MD:
Johns Hopkins University Press).
Briggs, D. & Arnott, D. (2004) Decision support systems failure, an evolutionary perspective,
Brown, R. V. (2006) Planning decision research with usefulness in mind: Toward quantitative
evaluation, in: F. Adam, P. Brezillon, S. Carlsson & P. Humphreys (Eds) Creativity and
Press).
Decision-support Systems, Document Number: MG-360-AF, Santa Monica: The RAND
Corporation.
Dodson, G., Arnott, D. & Pervan, G. (2006) The client and user in decision support systems:
Review and research agenda, in: F. Adam, P. Brezillon, S. Carlsson & P. Humphreys (Eds)
Creativity and Innovation in Decision Making and Decision Support, Vol. I (London, UK:
Decision Support Press).


