Assessing the Efficacy of Dynamic Adaptive Airport Planning

Airport Strategic Planning focuses on the development of plans for the medium–term and long-term development of an airport. Strategic planning can be done in many different ways. For airports, the dominant approach is Airport Master Planning, which results in a static plan that fails if the future turns out to deviate from the future anticipated during the development of the plan. To better cope with uncertainty, flexibility and adaptivity in the plans is necessary. However, how efficacious are such adaptive plans as compared to the more traditional static rigid plans? Using computational techniques, we find that only in a very narrow range of plausible futures a rigid plan performs better than the adaptive plan.

by: Jan Kwakkel

Introduction

Policymakers, business leaders, and planners face a wide variety of uncertainties that can substantially affect the outcomes of their plans or policies. Moreover, many of these uncertainties are beyond their direct control. Such strategic decision making problems are now frequently labeled as decision making under deep uncertainty. In order to improve the handling of deep uncertainty in long-term airport planning, various planning approaches have been put forward (see Kwakkel, Walker, & Marchau, 2010 for an overview). These approaches emphasize the need for a more thorough integrated forward-looking analysis of the uncertainties through techniques such as scenarios and the analysis of wild cards. However, because of the limited capability of forward looking techniques for anticipating rare events (Goodwin & Wright, 2010), there is a growing interest in flexibility and adaptability in plans in which a strategic vision of the future is combined with short-term actions and a framework that can guide future actions (Albrechts, 2004; Kwakkel, et al., 2010).

Although the toolbox of the airport planner has thus been gradually expanded, more progress needs to be made in incorporating these new methods into processes of policy design, choice, and implementation. However, this requires a controlled assessment and continuous improvement of the efficacy of these methods (Kwakkel, et al., 2010; Straatemeier, Bertolini, & Brömmelstroet, 2010). In planning literature, how to structure this controlled assessment is an ongoing debate (see Kwakkel & Van Der Pas, 2011 for an overview of positions). In this paper, we use a computer model of an airport in a series of computational experiments to assess the efficacy of a plan designed explicitly with flexible and adaptiveness in mind in comparison to a more traditional static plan. This offers a safe and controlled environment for testing new planning concepts, observing and reflecting on their effects, and possibly improving the concepts.

Photo 1: *Transavia.com Aircraft parked at Concourse D, Amsterdam Airport Schiphol. Photo by Hubert Croes.*

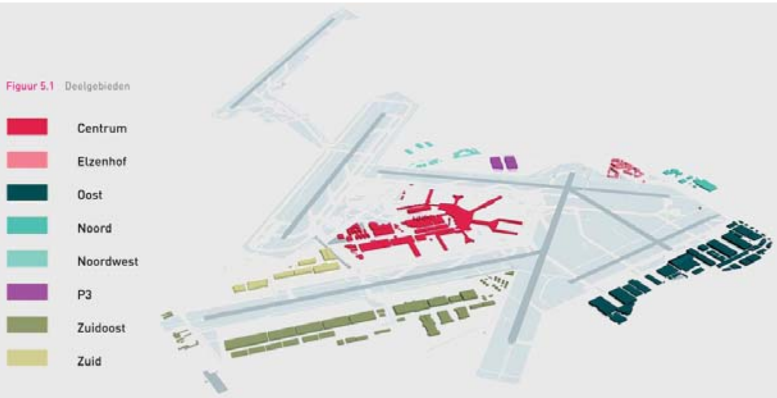
Since airport planning is decision making about the future, there are significant uncertainties present. There is simply not enough knowledge to accurately forecast the future. The performance of the plans derived from the different planning approaches needs to be assessed across these uncertainties. We have found that, when using simulation models for assessing the efficacy of infrastructure planning approaches, Exploratory Modeling and Analysis is an appropriate method for carrying out this assessment. Exploratory Modeling starts from the explicit recognition that, when researching uncertain complex systems, there are profound and diverse uncertainties present, the implications of which can be explored using computational experimentatio. (Bankes, 1993).

We intent to answer two related research questions.

✈ Question 1: given the multiplicity of plausible futures, what is the range of outcomes that both a static rigid plan and a dynamic adaptive plan can generate? If the dynamic adaptive is any good, its range of outcomes should be smaller; or, put differently, the risks associated with the dynamic adaptive plan should be smaller.

✈ Question 2: given the most favorable conditions for a static rigid plan, how well does the dynamic adaptive plan do in comparison? This question is motivated by the idea that, if an adaptive plan is to be attractive to decision makers, it should perform about equal to the static rigid plan or better, even under those conditions that most favor the rigid plan.

We combine a fast and simple simulation model of an airport that calculates key airport performance metrics with a scenario generator that can produce a very large ensemble of plausible future worlds. We evaluate the performance of a static plan and an explicitly flexible plan that over time can be adapted to the changing conditions across the ensemble of plausible future worlds. The results suggests that explicitly including flexibility in long-term plans, including a pre-specification when this flexibility will be utilized, can significantly improve plan performance under deep uncertainty.



Areas to be developed according to the 'Ruimtelijke Ontwikkelingsplan Schiphol 2015' (Spatial Planning 2015 Report) for Amsterdam Airport Schiphol. Source: http://www.schiphol.nl/InDeSamenleving/ToekomstSchiphol/ActueleProjecten1/Schiphol20072015.htm

Schiphol Airport Case Study

We choose to use the current challenges Amsterdam Airport Schiphol (the Netherlands) is facing in its long-term development as our case. Schiphol, as a secondary hub for KLM-Air France, faces a range of uncertainties that could affect the airport in different ways,. a multitude of policy documents from multiple stakeholders is readily available, the data necessary to quantify a model for calculating airport performance metrics is also available, and an outline for a dynamic adaptive plan for the long-term development of Schiphol has recently been presented (Kwakkel, et al., 2010). As such, it present a good test case for assessing the efficacy of adaptive planning.

We use a stylized version of the plans that are under consideration for the long-term development of Schiphol. We assumed the following goals: (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 There are several types of changes that are currently being considered to achieve these goals. The physical capacity can be expanded by using its existing runways and terminals more efficiently and/or building new capacity. More explicitly, among the options that are considered:

1. Add a new runway parallel to one of the existing runways
2. Move charter operations out of Schiphol. Lelystad and Eindhoven, which have a planned capacity of roughly 70,000 operations per year are the prime alternative airports and are operates by the Schiphol Group.
3. Limit available slots

For the static rigid plan, we assume that Schiphol will add the new runway, which will become operational in 2020. Furthermore, up to 70,000 operations will be moved away from Schiphol over the period 2015 to 2020. The dynamic adaptive plan is adapted from Kwakkel et al. (2010). The basic plan includes planning for all the infrastructure options without beginning to build any of them. The basic plan is made more robust through the actions outlined in Table 1. The contingency plan is outlined in Table 2.

Table 1: *Increasing the Robustness of the Basic Plan*

Vulnerabilities and Opportunities	Actions taken immediately to prepare for the Vulnerabilities and Opportunities
Demand for air traffic grows faster than forecast.	Prepare Lelystad and Eindhoven airport to receive charter flights
Increase in the population density in area affected by noise	Test existing noise abatement procedures such as the continuous descent approach, outside the peak periods (e.g. at the edges of the night) Maintain land use reservation that allows for building the new runway
Maintain current trend of decrease of environmental impact of aircraft	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 Invest in R&D, such as noise abatement procedures
Development of wind conditions due to climate change	Have plans ready to quickly build the sixth runway, but do not build it yet. If wind conditions deteriorate even further, start construction

Table 2: *The Contingency Plan*

Vulnerabilities and Opportunities	Contingency Planning
Demand for air traffic grows faster than forecast.	Monitor the growth of Schiphol in terms of aircraft movements. If this exceeds 450.000 operations, start building the new runway. The new runway becomes available five years later. If demand approaches 510.000 aircraft movements, more operations to Lelystad and Eindhoven. If it exceeds 510.000, reassess the plan.
Increase area affected by noise	Monitor area affected by noise. If area affected by noise increases by 20% compared to start year, limit the available slots. If it increases by 50%, tighten slot restriction further. If it increases by 75%, reassess plan. If area decreases by 20%, increase the slots.
Development of wind conditions due to climate change	Monitor the usage percentage of the cross-wind runway, If this increases by more than 10 percent compared to the start year, start the building of a new runway.

In order to explore and compare the performance of the two plans quantitatively, one or more models are needed. In this specific case, we chose to have a variety of generators, while we use a single model for calculating airport performance, which is based on the computational core of the HARMOS decision support system for airport strategic planning (Wijnen, Walker, & Kwakkel, 2008). The generators allow for generating demand volumes, wind conditions, technological developments, and changes in demographic patterns around the airport. Each generator component uses different structural assumptions.

Photo 2: *BMI Baby Boeing 737-300 taxiing to runway 36L 'Polderbaan' with Schiphol Centre in the background. Photo by Hubert Croes.*

Results

Question 1 is reduced to solving a boundary problem. For each outcome of interest, the upper and lower bound across both the model structures and parametric uncertainties needs to be determined. Technically, this requires the use of a non-linear optimization algorithm. For each outcome of interest, across each model structure and its parameter ranges, and across both plans, the minimum and maximum should be determined. The results of these optimizations are shown in Table 3. From this table, it can be concluded that the dynamic adaptive plan has a smaller bandwidth on all outcome indicators except for latent demand. The results for latent demand are explained by the fact that the dynamic adaptive plan has triggers in place to limit the size of the noise contour. If these are triggered, less demand is accommodated, thereby increasing latent demand. The high value of the practical annual capacity to accommodated demand ratio for the upper bound of the static rigid plan is explained by the large discrepancy between maximum annual throughput capacity, which determines the maximum accommodated demand, and the practical annual capacity. Such a high figure implies that the airport is heavily capacity constrained and is experiencing severe delays.

Table 3: *Performance Bandwidth of the Static Rigid Plan and the Dynamic Adaptive Plan*

Outcome Indicators	Static Rigid Plan	Dynamic Adaptive Plan
Size of 65 LDN contour after thirty years (km^2)	13-64	10-47
Max. size of 65 LDN contour (km^2)	18-64	18-48
Cumulative Average Casualty Expectancy (ACE)	1-3	1-2
Practical annual capacity - accommodated demand ratio after thirty years	0.3-2.5	0.9-1.1
Max Practical annual capacity -accommodated demand ratio	0.9-2.5	0.5-1.1
Accumulated latent demand (flights)	0-5,060,00	0-8,291,000
Cumulative CO emission (kg)	21,500-196,000	19,800-104,000

In order to answer the second question, we used the following approach. First, we identify the combination of uncertain parameters under which the static rigid plan performs the best compared with the dynamic adaptive plan. So, we try to find the best case for the static rigid plan compared with the dynamic adaptive plan. Once this point is identified, all uncertain parameters apart from demand growth and the wide body ratio are fixed to their values at this point. The choice for demand growth and wide body ratio is motivated by the observation that the main uncertainties in airport strategic planning are about the size and composition of future demand (Burghouwt, 2007; de Neufville & Odoni, 2003). For both, deliberately, a wide range has been used (Makridakis, Hogarth, & Gaba, 2009). Demand growth ranges from 0% to 6% increase per year, resulting in an exponential growth. For the wide body ratio, a linear change is used from the current ratio to a ratio for 30 years in the future. This end value ranges from 5% wide body flights to 50% wide body flights. A full factorial design is generated for the wide body ratio and demand growth per year, with 21 samples for each, resulting in 441 cases. For each case, the performance difference is calculated.

In order to determine the performance difference, we use Average Casualty Expectancy, Practical annual capacity - accommodated demand ratio, latent demand, size of the 65 LDN contour, and cumulative CO emissions as outcome indicators. Next, these indicators are normalized, using the maxima and minima from Table 3, so that they scale between 0 (bad) and 1 (good). That is, the actual outcomes are mapped to a unit interval in order to make them comparable. So, for example the maximum size of the noise contour (63.8 km2) is mapped to 0, and the minimum size of the noise contour (10.2 km2) is mapped to 1. The five normalized outcome indicators together are a performance vector that describes the performance of a plan. We then define the performance of a plan as the length of the performance vector, using the Euclidian norm. The performance difference between the two plans then becomes the difference in length between the performance vector of the static rigid plan and the performance vector of the dynamic adaptive plan.

The resulting performance differences are shown in Figure 1. Grayscale is used to indicate the value of the performance difference. If this value is below 0, the static rigid plan is 'better' than the dynamic adaptive plan. From this figure, we conclude that, even under the conditions that most favor the static rigid plan, this plan is only slightly better than the dynamic adaptive plan. Furthermore, the static rigid plan is better only in a relatively small area. So, if the wide body ratio and/or the demand growth deviate slightly from those that are the best for it, the static rigid plan will perform worse than the dynamic adaptive plan.

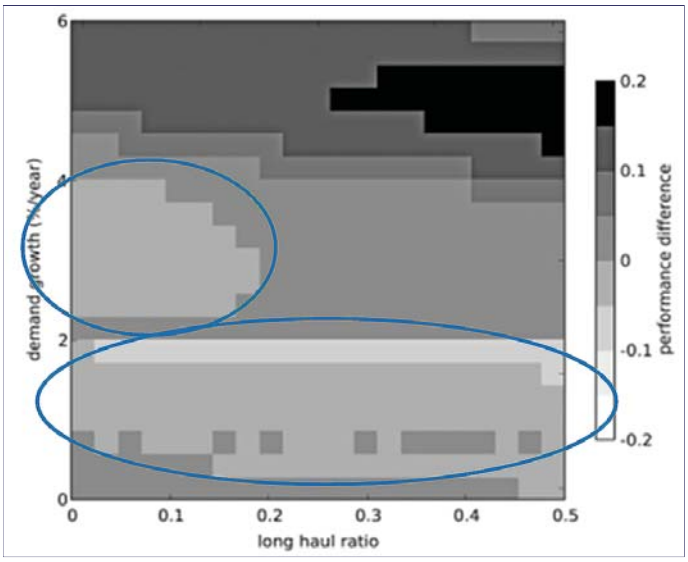


Figure 1: *Performance difference of the Dynamic Adaptive Plan compared to the Master Plan for that combination of uncertain parameters that most favor the Master Plan. The blue ellipses indicate the conditions under which the static rigid plan is performing better than the dynamic adaptive plan.*

Conclusion

In this paper, we used a computer model of Schiphol and a very large ensemble of plausible futures in a series of computational experiments to assess the efficacy of a static rigid plan and a dynamic adaptive plan. The results of the experiments showed that rigid static planning would perform better than dynamic adaptive planning only if the future demand were to fall within a narrow bandwidth. Conversely, if there is even small deviations from this bandwidth for e.g. uncertainty about future demand, the adaptive planning would be preferred. Given the high volatility of aviation demand in most parts of the world, adaptive planning is preferred over static planning.

This does not mean that airport planners should immediately switch to dynamic adaptive planning. Our experiments represent an idealized case. We compare a static rigid plan with a dynamic adaptive plan, assuming there are no subsequent actions to modify the static plan. In practice, frequently, parts of a static plan are deferred or sped up, operational changes are made, and, if necessary, formal updates to the plan are submitted. Our experiments have not taken such ad hoc deviations from and (formal) updates to the rigid plan into account. It is expected that if such ad hoc modifications to the static plan are accounted for in the experiments, the difference in performance between the two plans would be smaller.

About the Author

Dr.ir. Jan Kwakkel (j.h.kwakkel@tudelft.nl) works as a postdoc at Delft University of Technology, Faculty of Technology, Policy and Management. He teaches in the inter-faculty minor program Airport of the Future. His research focuses on handling uncertainty in decision making. This research was part of his PhD. Research.

Acknowledgement

This paper is based on a paper that is accepted for publication in Environment and Planning B: planning and design. That paper is expected to appear in mid-2012 and was co-authored by Warren Walker and Vincent Marchau.

References

Albrechts, L. (2004). Strategic (spatial) planning reexamined. Environment and Planning B: Planning and Design, 31(5), 743-758.

Bankes, S. (1993). Exploratory Modeling for Policy Analysis. Operations Research, 4(3), 435-449.

Burghouwt, G. (2007). Airline Network Development in Europe and its Implications for Airport Planning. Burlington, Vermont: Ashgate Publishing Company.

de Neufville, R., & Odoni, A. (2003). Airport Systems: Planning, Design, and Management. New York: McGraw-Hill.

Goodwin, P., & Wright, G. (2010). The limits of forecasting methods in anticipating rare events. Technological Forecasting and Social Change, 77, 355-368.

Kwakkel, J. H., & Van Der Pas, J. W. G. M. (2011). Evaluation of infrastructure planning approaches: An analogy with medicine. Futures, 43(9), 934-946.

Kwakkel, J. H., Walker, W. E., & Marchau, V. A. W. J. (2010). Adaptive Airport Strategic Planning. European Journal of Transportation and Infrastructure Research, 10(3), 227-250.

Makridakis, S., Hogarth, R. M., & Gaba, A. (2009). Forecasting and uncertainty in the economic and business world. International Journal of Forecasting, 24(4), 794-812.

Straatemeier, T., Bertolini, L., & Brömmelstroet, M. (2010). An experiential approach to research in planning. Environment and Planning B: Planning and Design, 37, 578-591.

Wijnen, R. A. A., Walker, W. E., & Kwakkel, J. H. (2008). Decision Support for Airport Strategic Planning. Transportation Planning and Technology, 31(1), 11-34.