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A Policy Analysis of Civil Aviation Infrastructure Options in the Netherlands

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PREFACE

This report summarizes the results of a policy analysis study that was performed by the European-American Center for Policy Analysis (EAC), which is a part of RAND. The study was performed for the Netherlands Ministry of Transport, Public Works and Water Management (V&W), Ministry of Housing, Spatial Planning and Environment (VROM), and Ministry of Economic Affairs (EZ), in support of the project called '*Toekomstige Nederlandse Luchtvaart Infrastructuur*' (TNLI) [Future of Dutch Civil Aviation Infrastructure]. RAND/EAC carried out the following research to help the project develop answers to some of the policy questions it was addressing and to inform the forthcoming public debate: *Assuming the Netherlands chooses to accommodate future air transport demands, assess infrastructure options for accommodating the demand, identify their positive and negative attributes, and draw conclusions about them.* The study was carried out during the period August 1995-October 1996.

In addition to this document, which presents a summary of the analysis of the infrastructure options, the study has produced three written products:

- A Research Brief, which is a brief description of the primary findings of the project.
- A description of the scenarios developed for the project [*Scenarios for Examining Infrastructure Options in the Netherlands*, EAC DRU-1513-VW/VROM/EZ, January 1997].
- A framework for an adaptive policymaking process, which can be used to devise a policy for civil aviation that addresses the high levels of uncertainty confronting civil aviation policymakers [*Adaptive Policies, Policy Analysis, and Civil Aviation Policymaking*, EAC DRU-1514-VW/VROM/EZ, January 1997].

The analysis and conclusions presented in this document should be of direct help to the TNLI project team in its preparation of a *Perspectieven Nota*, which is designed to help the Dutch Cabinet develop a view on an integral policy vision for the entire civil aviation system of the Netherlands. The information in the document should also be of interest to stakeholders who will be participating in the forthcoming public debate on the future of the Dutch civil aviation system, and the methodology should be of interest to transport policy analysts worldwide. Indeed, many of the conclusions

and much about the methodology should be directly applicable to civil aviation policy issues being faced by other governments.

The EAC, an independently-chartered European unit of RAND, is located in Delft, the Netherlands. It operates as a foundation (Stichting), chartered in The Hague under Dutch law. The mission of the EAC is to conduct interdisciplinary analyses of public policy problems facing Europe and North America; to convey the results of these analyses to the policymaking community, the research community, and the public at large; and to foster cooperation among researchers in all parts of Europe and North America. The EAC seeks to accomplish its mission through research projects of interest to governments and society as a whole. EAC research is conducted alone, in conjunction with individuals and research organizations in the Netherlands and throughout Europe, and through close cooperation with other RAND sites.

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ACKNOWLEDGMENTS

Policy analysis projects usually involve the assistance of many individuals and organizations. The study reported on here required a great deal of such help, and was fortunate to have received it. Help was needed because of the diversity of the topics considered, our dependence on other individuals and organizations for essential information, and the political nature of aspects of the problem being addressed.

When help is received from so many sources, it is difficult to individually thank everyone who contributed in some way. We mention a few names here, and list the names of some of the others in Appendices A and B. Of course, acknowledging various individuals does not imply that those who assisted us are responsible for, or agree with, our findings. The responsibility for any shortcomings rests solely with the authors.

Besides the authors of this report, the most important participants in the study were several members of the Netherlands Ministry of Transport, Public Works and Water Management (V&W), Ministry of Housing, Spatial Planning and Environment (VROM), and Ministry of Economic Affairs (EZ), who were members of the TNLI Project Team. They met regularly to review the project's status, identify the next steps to be taken, assign responsibilities for the next steps, and provide liaison with the policymakers. Throughout the project they participated in the research and gave helpful advice and information. They also read this document and suggested revisions to it. The members of the TNLI Project Team were:

Mrs. drs. N.M. Don, V&W, Directorate General of Civil Aviation (Chairman)

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A Steering Group was formed to provide guidance on the scope and emphasis of the research and to which the policy conclusions were presented. The Steering Group was chaired by Mr. mr. J.W. Weck, Director General of Civil Aviation, Ministry of Transport, Public Works and Water Management. His support of our work was crucial to the project's success. The members of the Steering Group were:

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An Analytic Support Group was formed to provide expert advice to our study. The members of this group played valuable roles in the scenario development, model development, and quantitative analysis efforts. The members of the Analytic Support Group were:

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Drs. H.E. ten Velden, VROM, National Spatial Planning Bureau

A *Commissie van Wijzen* was commissioned by the Steering Group to vet the scenarios developed for the TNLI Project. The *Commissie* consisted of:

Prof. dr. J.M. Cramer, Philips Consumer Electronics, Environmental Competence Centre

Prof. K. van der Heijden, Department of Management Science, University of Strathclyde, Glasgow

Prof. P. Nijkamp, Free University of Amsterdam, Faculty of Economics and Econometrics

Prof. dr. F.J.H.P. Don, Central Planning Bureau

A series of Round Table Meetings was held to elicit stakeholders' concerns about the Dutch civil aviation system. We would like to thank all who participated for the valuable information they provided for this project. The names and affiliations of the participants appear in Appendix A. The Round Table Meetings were organized and run jointly with Kolpron Consultants. Kolpron sent out the invitations, led each of the discussions, and provided written summaries of the meetings.

As part of the process of understanding the problems related to the Dutch civil aviation system, the infrastructure options that might be implemented to address those problems, and ways of estimating the consequences of those options, we met with many individuals. These persons worked for the government, for universities, for research organizations, for companies involved in civil aviation, and for groups concerned with mitigating the negative effects of civil aviation. We are grateful for their assistance. The names and affiliations of these persons are listed in Appendix B.

Although RAND/EAC was the prime contractor for this study, we collaborated with three other organizations in carrying it out. These organizations developed some of the models that generated the information we used to assess the infrastructure options. The model developers were: STRATAGEM for the model that generated the air transport demands, the Nederlands Economic Institute (NEI) for the economic effects model, and the Nationaal Lucht- en Ruimtevaart Laboratorium (NLR) for the model that estimated the aircraft noise and emissions effects. Aart Kappers of STRATAGEM helped us to design and build the database of model outputs.

GLOSSARY

Aircraft movements. The total number of landings and take-offs at an airport.

Air Traffic Control (ATC). The government-regulated system of rules, procedures, instruments, and personnel intended primarily to assure flight safety.

Assessment. A stage in the analysis in which infrastructure options are compared in terms of the criteria.

Cargo. Goods carried on an aircraft and covered by an airway bill. Goods trucked under an airway bill (i.e., by "air trucking") are not included.

Case. A particular combination of an infrastructure option and scenario.

Comparison Point. The results of the assessment of infrastructure options are presented as changes relative to this situation. The comparison point is based on the assumptions made in the European Renaissance-European Liberalization (ER-ELi) scenario of PKB-Schiphol for the year 2015. It represents a demand of 38.6 million passengers, 2.1 million tonnes of cargo, and 432,000 aircraft movements.

Criterion. A consequence of the implementation of an infrastructure option that is relevant for choosing among alternative options.

Ground access. Highways, local streets, fixed guideway systems, and public and privately operated transit services linking an airport to the area that it serves.

Hub. A hub is a large airport at which one or more airlines serve many destinations with high frequencies and use a dedicated transfer system (banks) in order to facilitate large numbers of on-line connections. As a result, over 30 percent of the passenger movements at a hub are transit and transfer passengers.

Hub-and-spoke network. A pattern of airline routes that brings direct flights from many points (the spokes) to a centrally located airport (the hub). Flight schedules allow passengers to transfer quickly between flights during periods when many aircraft are simultaneously at the hub location. Such a route structure is intended to maintain high levels of aircraft utilization and loading. Airline hubs increase the proportions of transfer passengers (vs. origin/destination, or O/D, passengers).

Infrastructure option. A change to the infrastructure in the Dutch civil aviation system (e.g., building a new airport or expanding the capacity of an existing airport). Three specific infrastructure options are building a new airport in the sea, expanding the capacity of Schiphol, and building an all-cargo airport in a lake.

Noise emissions. The sounds produced by aircraft engines.

Noise immissions. The total noise individuals experience on the ground from overflying aircraft. This experience is affected by such things as the distance between the individuals and the aircraft, weather and wind conditions, and whether it is day or night.

Origin/Destination (O/D) passenger: A passenger starting or ending his/her air travel at an airport (i.e., not a transfer or transit passenger).

Passenger movement. A departure or arrival of a passenger at an airport.

Transfer passenger. A passenger arriving by one flight and continuing the journey by another flight (counts as two passenger movements).

Transit passenger. A passenger arriving and departing by the same transit flight (same flight number) (counts as one passenger movement).

Scenario. A description of some hypothetical future state of the civil aviation system (in this case, in the year 2025+), excluding the policy options to be examined. The scenarios we developed considered only the factors that might strongly affect the cost or performance of civil aviation policy options. We call these factors *scenario variables*. These factors include *external developments*, such as changes in the economy, settlement patterns, scarcity of resources, attitudes of people, and political factors. They also include factors internal to the system, which we call *system variables*.

Vrijwaringszone. A protected zone around an airport in which no new houses may be built. Currently, this zone is defined only for Schiphol Airport.

1. INTRODUCTION

1.1 BACKGROUND AND OBJECTIVES

The Dutch Government is in the midst of a reassessment of its policies related to civil aviation. It is in the process of preparing a *Perspectieven Nota* as a prelude to developing a revised version of its Civil Aviation Areas Structure Scheme (SBL). (The SBL states a concrete elaboration of the physical and environmental consequences of each airport in the Netherlands, and indicates the demand for airport capacity for commercial air transport and for general aviation.)

One of the catalysts for this reassessment is the fact that the recent growth in commercial civil aviation traffic in the Netherlands has exceeded expectations. For example, in 1995, Schiphol airport's passenger and freight volumes were approximately those that might have been expected in 2004 from the trends assumed in the scenario that was used during the recent Schiphol planning process. (This scenario formed the basis for the government's new policy on Schiphol.) This high growth in traffic occurred despite the fact that economic growth, one of the key factors driving the growth of air traffic in the models used to develop the scenario, turned out to be considerably lower than what had been assumed.

One of the elements that will feed into the preparation of the *Perspectieven Nota* is a study that posits alternative contexts within which the Dutch civil aviation system may have to operate in the future, and assesses the performance of alternative configurations of airports in those contexts. Such a study was called for by the Ministers of Transport, Public Works and Water Management (V&W), Housing, Spatial Planning and Environment (VROM), and Economic Affairs (EZ) in their "Commentary on PKB3" [Project Mainport & Milieu Schiphol, February 1995]. In this document, they said that the government would soon present an integral policy vision for the entire civil aviation system of the Netherlands. As a result, the Rijksluchtvaartdienst (RLD) prepared a "Plan of Approach" [Ministerie van Verkeer en Waterstaat, 1995] that describes the process of preparing this integral policy vision. This process includes the preparation of a *Perspectieven Nota*, which would be the Cabinet's view

on what this vision should be. The Nota would be used as a basis for a public debate on the Dutch civil aviation system, which would lead to the integral policy vision.

In the summer of 1995, a project was begun to prepare the *Perspectieven Nota*. This project was called the '*Toekomstige Nederlandse Luchtvaart Infrastructuur*' (TNLI) [Future of Dutch Civil Aviation Infrastructure] project. The "Plan of Approach" specified that one of the inputs to the TNLI project would be the results of an analysis that investigated possible future developments of demand and capacity of air transport, alternative infrastructure options that could be implemented to meet these future situations, and societal demands and expectations that would influence the choice among those alternatives.

RAND's European-American Center for Policy Analysis (*EAC*) carried out the analysis of the infrastructure options. This document summarizes that work. It also draws insights and conclusions from the work that should be useful in preparing the *Perspectieven Nota*. Figure 1.1 depicts graphically the relationship between this project and the TNLI project, and shows the process that will be used to produce the *Perspectieven Nota*.

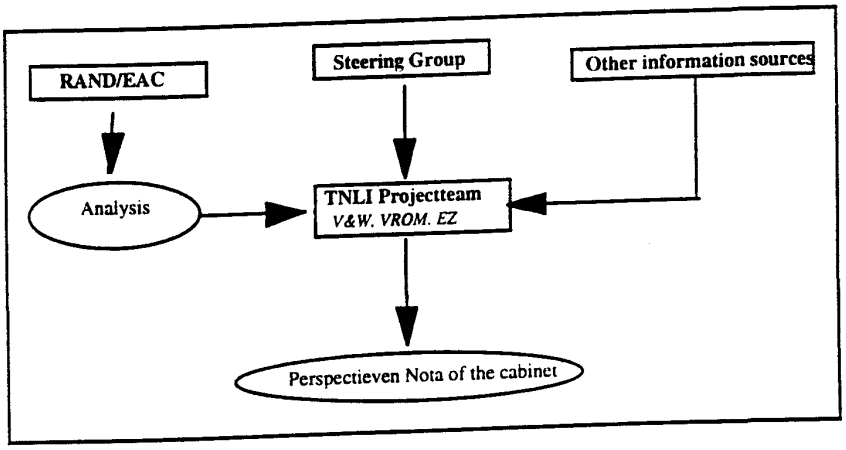

Figure 1.1-TNLI Project: Organization and Process

The Dutch Government's Policy Question

Air transport benefits the Dutch economy in many ways. Approximately 70,000 persons are directly employed by airports and airlines in the Netherlands. Of this, approximately 40,000 persons are directly employed at Schiphol Airport, and an equal number of jobs are indirectly generated in the national economy from its activities

[Amsterdam Airport Schiphol, 1995]. The availability of a wide range of high quality air services in the country also helps create a favorable investment climate and promotes international trade.

Nevertheless, the direct and indirect environmental effects of air transport at both the local and global levels are increasingly becoming problems that need to be addressed. In addition, regions close to airports suffer other negative effects, such as surface traffic congestion and aircraft noise. And, these negative effects tend to increase as the air traffic increases.

These facts, together with information obtained from interviews with the members of the TNLI Steering Group (which is comprised of some of the top managers of the client organizations) resulted in the following statement of the question to be addressed by the TNLI project:

> *The demand for infrastructure for civil aviation transport in the Netherlands may continue to increase. Activities related to civil aviation have social, economic, safety, environmental, spatial, accessibility, and cost consequences. The question the nation must answer is whether or not to accommodate the demand in light of these consequences, and, if so, how.*

RAND/EAC's Research Task

As shown in Figure 1.2, developing answers to the policy question posed to the TNLI project that match the nation's goals, objectives, and values requires a great deal of information and analysis. We carried out the following research to help the project develop an answer to the policy question and to inform the forthcoming public debate:

> *Construct several possible future worlds in which the Dutch civil aviation system might have to function. For each of those worlds, assess infrastructure options that would enable the demand for air transport to be accommodated, identify their positive and negative attributes, and draw conclusions about them.*

In preparing the *Perspectieven Nota*, the TNLI project will add to this analysis insights about their assessment of non-infrastructure policy options, such as ways of making more efficient use of existing infrastructure (e.g., through improvements in the Air Traffic Control system) and ways to shape demand (e.g., by changing the prices for air travel). In addition, it will discuss the broader question (which

needs to be answered first): whether the country should accommodate the demand, and if not, what instruments can be used to constrain it, and what might be the consequences of their use.

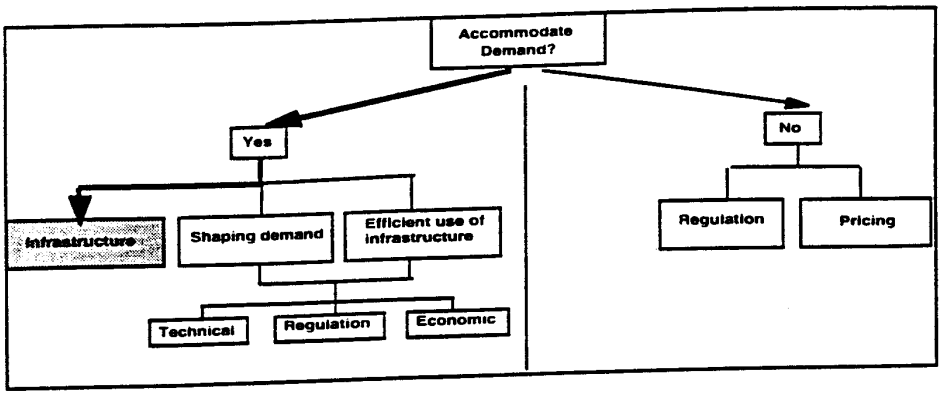

Figure 1.2-Analysis required to answer policy questions

1.2 PRODUCTS OF THE STUDY

In addition to this document, which presents a summary of the analysis of the infrastructure options, including a description of the methodology and the conclusions, the project has produced three written products:

- A Research Brief, which is a brief description of the primary findings of the project.
- A description of the scenarios developed for the project.
- A framework for an adaptive policymaking process, which can be used to devise a policy for civil aviation that addresses the high levels of uncertainty confronting civil aviation policymakers.

The information in the report on scenarios is summarized in Sec. 2 of this report, and is presented in detail in [European-American Center for Policy Analysis, 1997a]. The report on the adaptive policymaking process [European-American Center for Policy Analysis, 1997b] is complementary to this report.

The report on adaptive policymaking shows how the information from the analysis of infrastructure options can be combined with information on non-infrastructure options to create a policy that can be adapted over time in response to a changing world. In the context

of the number of plausible scenarios for the future of Dutch civil aviation, it may not be possible to devise a single static policy that will perform well in all of these scenarios. For example, promising infrastructure options may be less than ideal in the context of particular scenarios either because they fail to exploit opportunities that arise in those posited futures, or because key assumptions necessary for their performance turn out not to be true. Also, uncertainties about future economic, political, and technological conditions will decrease over the course of time as new information becomes available. The adaptive policymaking framework illustrates how the policymaking process can accommodate the pragmatic reality that actual policy is usually adjusted as new information becomes available.

1.3 OVERVIEW OF THE SYSTEM

This project studied the commercial aviation system of the Netherlands. The system can be divided into two parts: the supply system, and the demand system. The main elements of the supply system are the airlines, the air traffic control system, and the national and regional airports. The infrastructure options we analyzed all related to changes in the supply of airport capacity.

Figure 1.3 shows the current system of airports. There is one national airport (Amsterdam Airport Schiphol) and five regional airports (Rotterdam Airport, Maastricht Aachen Airport, Groningen Airport Eelde, Eindhoven Airport, and Twente Airport). Table 1.1 presents some information about the passenger movements and cargo volumes that each of these airports handled in 1995.

Table 1.1

Commercial Traffic at Airports in the Netherlands, 1995

Airport	Passenger Movements	Freight (tonnes)	Aircraft Movements
Schiphol	24,856,000	978,000	290,689
Rotterdam	396,000	11,000	16,409
Maastricht	212,000	35,000	10,762
Groningen	43,000	-	3,622
Eindhoven	211,000	-	11,729
Twente	22,000	-	3,797

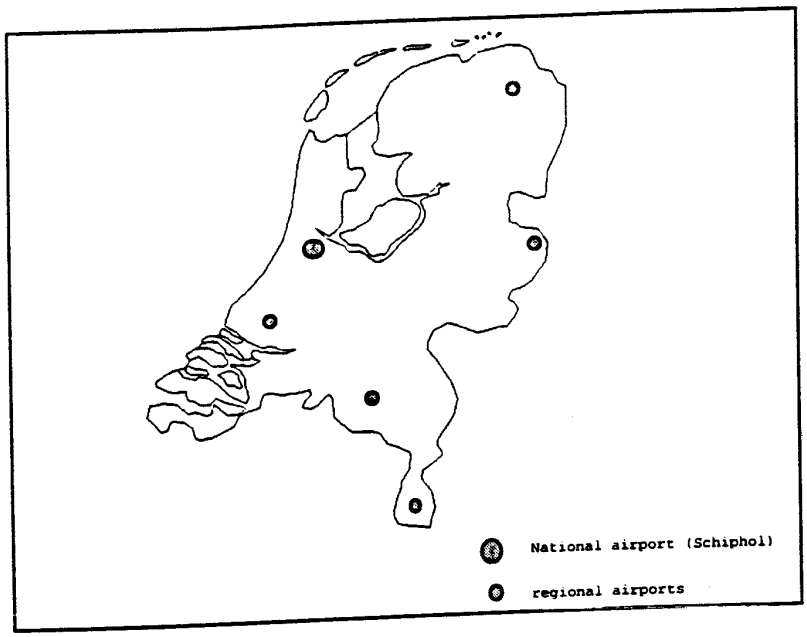

Figure 1.3-The current system of national and regional airports

The demands for air transport considered in the analysis are passenger and cargo demands for transport to, from, or through the Netherlands. The planning horizon for the project was chosen to be the year 2025 and beyond (we refer to this time horizon as 2025+).

1.4 ORGANIZATION OF THIS REPORT

The analysis looked at a range of infrastructure options and assessed the relative performance of each one in a number of different future worlds. A range of performance criteria were used to compare the options, including aircraft emissions, noise, ground access emissions, third party risk, financial costs, and the effects on the national economy. Section 2 describes the approach that was used in the analysis. Section 3 presents the assessment of the infrastructure options. The project's major conclusions and observations can be found in Sec. 4. Some specialized terms that are used in this report are defined in the Glossary.

2. THE FRAMEWORK FOR ANALYZING INFRASTRUCTURE OPTIONS

2.1 OVERVIEW

The analysis was performed using a structured approach developed at RAND to assist policymakers in evaluating public policy options in situations involving complex systems with multiple measures of performance that involve competing interest groups with different, possibly conflicting, goals. The approach is simply called *policy analysis*. It has been applied successfully to such different areas as national freight transport policy, national water policy, drug policy, educational policy, and national defense planning and budgeting.

No matter what the system being studied, the policy analysis process generally involves the same basic elements and involves performing the same set of steps (see, for example, [Miser and Quade, 1985, p. 123]). In the context of civil aviation infrastructure planning, there are many airport configurations (we call them *infrastructure options*) that could be implemented. Each infrastructure option will have many different types of effects, including effects on air quality, safety, noise, jobs and other economic indicators, as well as on government expenditures and on the service characteristics of the transport system. Policy analysis offers a way to examine the multiple consequences of such options and to present the information and insights in a way that promotes understanding of the tradeoffs available to policymakers, and that facilitates the policy debate among diverse stakeholders. The infrastructure options examined in this analysis are described in Sec. 2.4.

The evaluation of alternative infrastructure options needs to take place in the context of the future world in which they will have to function. But, the future is uncertain. One way to deal with this uncertainty is to construct alternative possible scenarios and look for options that perform reasonably well in some or all of them. A *scenario* is a description of a hypothetical future state of the world, including a consideration of the major uncertainties encountered in moving far into the future. The scenario pays attention to developments within the system and to those outside the system that affect the system, excluding the infrastructure options to be examined. We constructed

five scenarios for a year 2025+ that focus on (1) the world of civil aviation, and (2) changes both inside and outside the civil aviation system that are relevant for making policy decisions about investments in civil aviation related infrastructure in the Netherlands. The scenarios are described in Sec. 2.2.

We use the term *effects* to refer to the consequences of the infrastructure options. As part of the analysis, we estimated a wide range of effects (both qualitative and quantitative) that would be useful in comparing the performance of the various options. We identified emissions, noise, safety, the economy, spatial aspects, and financial costs as the relevant categories of criteria for evaluating the options. Based on discussions with stakeholders, members of the client organizations, and other sources, we defined both qualitative and quantitative effects that would be used in our analysis. These are discussed in Sec. 2.3.

The passenger and cargo demands in each of the various scenarios and the quantitative effects of the infrastructure options for the various scenarios were estimated with the use of data and models. In particular, models were built to estimate the economic effects, noise, aircraft exhaust emissions, ground access emissions, and financial costs of the various infrastructure options for each of the scenarios. Information about the models is given in Sec. 2.3. The assumptions that were made in each of the models are summarized in Appendix C.

Governments have the option of not accommodating demand by placing constraints on airport capacity or by providing infrastructure that is insufficient for meeting the demand. The analysis included no policies that constrained the capacity of airports in the Netherlands. There were two reasons for not including such policies in the analysis. First, the analysis was focused on infrastructure options, not on other types of options (see Fig. 1.2). Second, because the primary objective of the analysis was to assess infrastructure options, the models we used were developed specifically to facilitate a comparison of the costs and benefits of various infrastructure options for each of a number of different scenarios. These models could not be used to evaluate the impacts of constraints on airport capacity.

An example will illustrate this point. Consider the following two situations. In the first (constrained) case, there is a demand

for Schiphol of 60 million passengers, and 44 million of these passengers are accommodated. In the second case, there is a demand of 44 million passengers, and all of this demand is accommodated. The resulting economic, environmental, and other effects of accommodating 44 million passengers will be different in the two cases. The effects will be different because the aircraft mix, the proportion of transfer and O/D passengers, and the proportion of business and leisure passengers will be different. We estimated the effects for the second case (because we built models to estimate the aircraft mix and other characteristics of demand for this case). In order to model the first case, we would have needed to model the relationship between capacity constraints and airline behavior, which was not needed to compare the impacts of infrastructure options for accommodating demand in the different scenarios.

2.2 SCENARIOS

Five scenarios (descriptions of hypothetical future states of the world) were developed for the TNLI project. The scenarios were not given names. They are referred to as Scenario 1, Scenario 2, Scenario 3, Scenario 4, and Scenario 5. The scenarios focus on two things: (1) the world of civil aviation, and (2) changes -- both inside and outside the civil aviation system -- that are relevant for making policy decisions about investments in civil aviation related infrastructure in the Netherlands.

These scenarios were specifically developed to explore future developments that could be relevant for the development of civil aviation policies for the Netherlands. They are not predictions or forecasts about the future, nor do they represent the most likely future developments. The scenarios do not tell us *what will happen* in the future, rather they tell us *what can happen*. They are not an inventory of all the changes affecting civil aviation that can occur in the future -- encompassing all possible changes in five scenarios is impossible. However, each scenario, although a single point in the array of possible futures, represents a family of changes that fall within the category represented by the scenario.

The process that we used in developing the scenarios consists of the following six steps (see Fig. 2.1):

1. Identify possible structural changes in the civil aviation system

2. Identify the assumptions underlying the structural changes (i.e., the logic relating the assumptions to the structural changes)

3. Categorize the assumptions as predetermined (fairly certain) or uncertain

4. Identify the uncertain assumptions that would have a large impact on the demand for air transport

5. Develop the scenarios

6. Quantify the scenarios (i.e., turn the scenario assumptions into numbers that could be used as inputs to the various models)

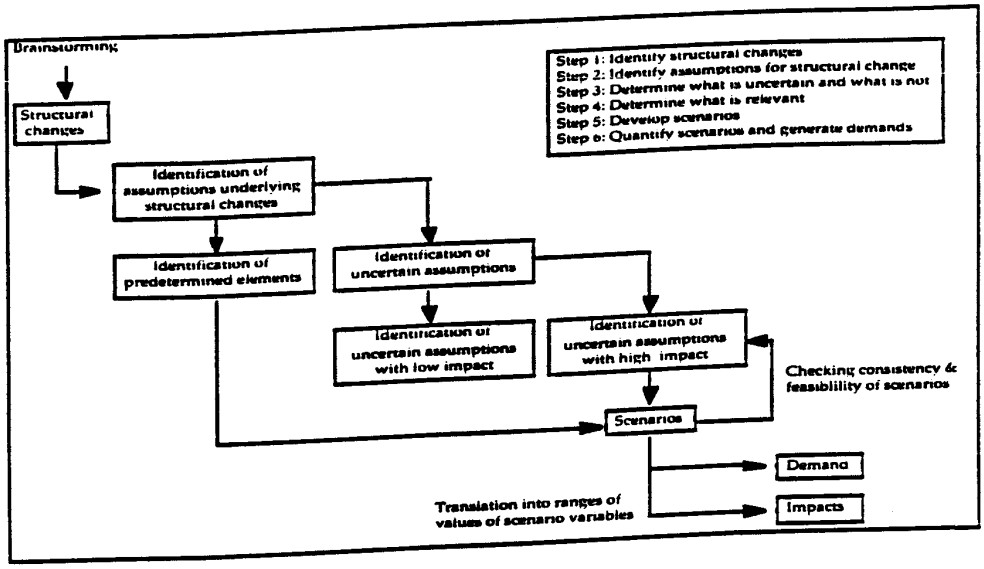

Figure 2.1-The scenario development process

The five scenarios differ in terms of the assumptions that are made about (1) worldwide growth of civil aviation, (2) the configuration of the civil aviation system in Europe, (3) civil aviation policies within the European Union, (4) the development of competing transportation systems, (5) airport capacity in Europe, and (6) aircraft technology. Table 2.1 gives an overview of the five scenarios. A scenario describes a hypothetical future state of the world in the distant future (the year 2025 and beyond). Their quantification focuses on the year 2025. A brief description of each of the scenarios follows the table. For more detail on the scenarios and their development, see [European American Center for Policy Analysis, 1997a].

Table 2.1

Scenarios for 2025+ for the TNLI Project

Scenario No.	Worldwide CA	Role of the Netherlands	Annual Passenger Movements	Annual Tonnes of Cargo
1	Growth	One of six hubs	~ 103 mln	~ 7.7 mln
2	Growth	No hub	~ 40 mln	~ 2.3 mln
3	Growth	One of ten hubs	~ 64 mln	~ 4.6 mln
4	Downturn	One of three hubs	~ 82 mln	~ 10.0 mln
5	Downturn	No hub	~ 14 mln	~0.8 mln

Scenario 1

Air travel is growing, more people and cargo are flying than ever before. The airline industry is profitable. Cargo traffic is expected to grow faster than passenger traffic, since trade in high value goods has increased the volume of cargo being shipped by air. There has been considerable consolidation of the airline industry. Only a few carriers have survived deregulation. Another important development has been the growth of global airline systems. There is a very well developed hub-and-spoke network in Europe, with six hubs, one of which is in the Netherlands.

In terms of policies, the domestic markets of all EU countries are completely open to carriers from other EU countries and the system of bilateral general service agreements between countries has been replaced by a multilateral open skies regime between the EU and the United States as well as between the EU and most of the countries in the Far East.

The high speed train (HST) is the major competitor to air transport. This competition is limited to the intra-European trunk routes. Train travel is substituted for air travel on routes connecting the large European cities with hub airports. Adequate airport capacity exists at European airports and at American and Far Eastern points of origin. Mega-jumbos jets are in operation.

Scenario 2

Air travel is growing and the airline industry is profitable. Cargo traffic is growing fast, since trade in high value goods has increased the volume of cargo being shipped by air. There has been considerable consolidation of the airline industry. Only a few carriers have survived deregulation. Another important development has been the growth of global airline systems. There is a very well developed hub-and-spoke network in Europe, with six hubs. However, there is no airline hub in the Netherlands, mainly because no Dutch airline was able to survive as a major player in the world of global civil aviation.

In terms of policies, the domestic markets of all EU countries are completely open to carriers from other EU countries and the system of bilateral general service agreements between countries has been replaced by a multilateral open skies regime between the EU and the United States as well as between the EU and most of the countries in the Far East, however there are differences in policies in the Eastern and Western European countries.

The HST is the major competitor to air transport. This competition is limited to the intra-European trunk routes. Adequate airport capacity exists at European airports and at American and Far Eastern points of origin. A very large new airport has been constructed in Paris. Mega-jumbos jets are in operation.

Scenario 3

Air travel is growing and the airline industry is profitable. Cargo traffic is growing fast, since trade in high value goods has increased the volume of cargo being shipped by air. There is strong economic growth in Eastern and Southern Europe, but the EU has not expanded. The level of consolidation in the aviation industry is low to moderate. There are large numbers of airlines, including regional airlines and niche players. The route network consists of several small hubs and many O/D connections. There are ten European hubs, one of which is located in the Netherlands.

In terms of policies, European unification has not progressed as far as planned or as smoothly as had been expected. There are no multi-lateral open skies treaties between the EU and the US or between the EU and the Far East, and there has been no expansion of bilateral open-skies agreements between countries. Competition among countries to attract passengers and cargo is high.

The HST serves as a feeder to flights from the air hubs. It is a strong competitor to air on the highly traveled trunk routes. No major European airport has excess capacity and mega-jumbo jets are in operation.

Scenario 4

There has been a global downturn in demand for civil aviation, largely due to new information about adverse environmental effects of aviation and a tripling of fuel prices. There are fewer airlines, with only three European airlines. The aviation network primarily serves the intercontinental market. There are three major aviation gateways to Europe, one of which is in the Netherlands.

In terms of policies, there is more regulation of air transport and all subsidies to airlines have been eliminated.

There has been massive substitution of HST for air transport. The extent of the HST network has increased, with links to and within Scandinavia, Southern Europe, and the United Kingdom. The airports have adequate capacity and mega-jumbos jets are in operation.

Scenario 5

There has been a global downturn in demand for civil aviation, largely due to new information about adverse environmental effects of aviation and a tripling of fuel prices. There are fewer airlines, with only three European airlines. The aviation network primarily serves the intercontinental market. There are three major aviation gateways to Europe. However, there is no airline hub in the Netherlands.

In terms of policies, there is more regulation of air transport and all subsidies to airlines have been eliminated.

There has been massive substitution of HST for air transport. The extent of the HST network has increased, with links to and within Scandinavia, Southern Europe, and the United Kingdom. The airports have adequate capacity and mega-jumbos jets are in operation.

2.3 CRITERIA FOR ASSESSING EFFECTS OF INFRASTRUCTURE OPTIONS

During the initial phases of the project we held round table meetings (RTMs) with representatives of the following stakeholders:

- Governmental agencies and regulators
- Dutch airport owners and users
- Stakeholders with a regional economic interest
- Stakeholders with a regional spatial interest
- Stakeholders with a commercial interest
- Employers and employees of airport-related businesses
- National environmental interest groups
- Regional and local citizen and environmental interest groups
- Stakeholders with other transportation interests

Based on these RTMs, literature, and additional internal and external discussions, we identified a set of quantitative and qualitative criteria. The types of criteria that were used in the analysis to assess a particular 'case' (that is, a combination of an infrastructure option and a scenario) provide the ability to examine the relative differences among the various infrastructure options within a particular scenario.

Computer models were used to provide insights and to test hypotheses about possible infrastructure options. They enabled us to examine some of the consequences of combinations of civil aviation scenarios and infrastructure options. The models were designed to explore the implications of uncertainties in the future world of civil aviation for policy decisions regarding civil aviation infrastructure, to provide a level playing field for comparing alternative infrastructure options, and to provide insights into the costs and benefits of the infrastructure options for the various scenarios.

Computer models were developed for estimating demand, economic effects, costs, noise, aircraft exhaust emissions, and ground access emissions associated with the scenarios and infrastructure options. They were developed by the EAC and three collaborating organizations. The models and their developers are listed in Table 2.2. Figure 2.2 shows how the models fit together conceptually.

Table 2.2

Models and Their Developers

Model	Developer
Economic effects	NEI
Noise	NLR
Aircraft exhaust emissions	NLR
Ground access emissions	EAC
Demand	STRATAGEM
Costs	EAC

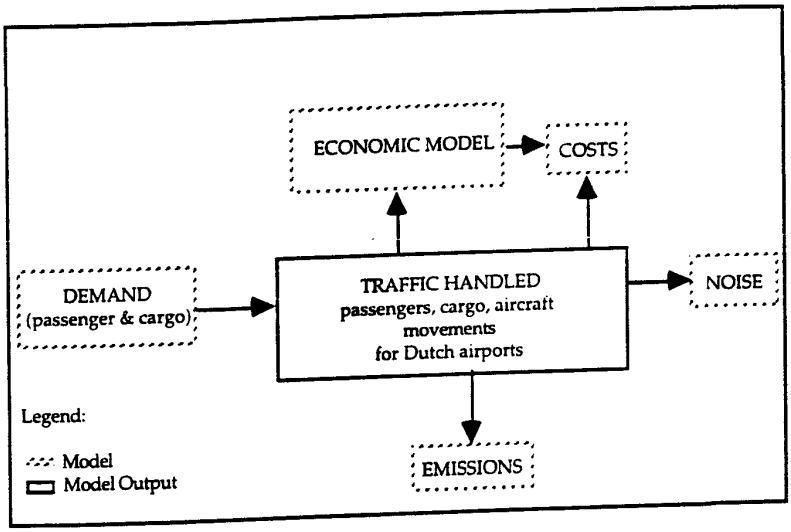

Figure 2.2-Interrelationships among the models

The demand model produces sets of numbers for a scenario that are estimates of future demands based on the assumptions made in that scenario. Demands are represented in terms of the number of aircraft movements, tonnes of cargo, aircraft mix, number of O/D, transfer, business, and leisure passengers, and the share of these passengers carried by the home carrier and by foreign carriers. These numbers can be divided into two categories, each having a number of subcategories, as shown below.

Level of demand:
1. number of aircraft movements
2. number of passengers
3. volume of cargo

Composition of demand:
1. aircraft mix
2. number of O/D passengers
3. number of transfer passengers
4. number of business passengers
5. number of leisure passengers
6. passengers carried by home carrier
7. passengers carried by foreign carrier

The model used to estimate national economic effects uses the demand model's estimates of passenger, cargo, and aircraft movement volumes to estimate the effects of the resulting civil aviation activity on employment, value-added, and demand for land, office space, and land transport. The model considers the economic picture painted by the scenario, as well as the specifics of the infrastructure option (the number, location, and function of national airports). Both direct and indirect employment effects are estimated. The direct effects are those jobs that are directly related to aviation activities in the Netherlands. Indirect effects are jobs created by intermediary deliveries and by the attractiveness of an airport and its location. The indirect effects, although important, are difficult to measure. We made conservative estimates of the indirect effects. This means that the indirect effects, and, therefore, the total effects on Dutch employment, may be larger than what we have estimated.

The noise model and the aircraft emissions model use the number of aircraft movements by aircraft type from the demand model to estimate their impacts (indicator for the ground surface within the noise immission contour of LDN 70 dB(A) and total exhaust emissions of the landing and takeoff cycle of all flights up to 10,000 feet, respectively).[1]

The ground access emissions model uses the demand figures to estimate the emissions generated by O/D passengers, employees, and cargo traveling to and from the airport.

The cost model estimates the financial cost of providing capacity at the national airport(s) to meet the demand estimated for a given case.

The numbers produced by the models are not important in themselves. It is the relative differences in those numbers that are important. The most important objective of the assessment of infrastructure options was to provide insights into the relative performance of the options in each scenario. In other words, for a

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[1] Noise *immissions* are different from noise *emissions*. Noise emissions are the sounds produced by the aircraft engines. Noise immissions are the total noise individuals experience on the ground from overflying aircraft. This experience is affected by such things as the distance between the individual and the aircraft, weather and wind conditions, and whether it is day or night.

given scenario and measure of performance, the assessment was intended to shed light on which options performed best. Our intention was to be able to make the following sorts of statements: for some given level and composition of demand (i.e., a scenario), Option A is better than Option B in terms of cost and environmental effects, but not as good in terms of its economic effects.

The quantitative information was combined with qualitative information in order to assess the various infrastructure options. Table 2.3 gives an overview of the categories and types of criteria that were used in the analysis. Appendix D provides a complete list of the quantitative and qualitative criteria used.

Table 2.3

Categories and Examples of Criteria Used in the Analysis

System aspects • Interference with use of airspace for military purposes • Effects of weather
Mobility aspects • Interference of airport-related traffic with local non-airport-related transportation activities • Integration with HST network
Economic aspects • Employment • Gross value added
Environmental aspects • Emissions from landings and takeoffs • Ground access emissions • Noise immissions • Third-party risk • Visual intrusion
Spatial aspects • Land needed for the infrastructure option • Land becoming available for noise-sensitive functions
Costs of infrastructure options • Pre-construction costs • Construction costs • Additional costs

2.4 INFRASTRUCTURE OPTIONS

Based on meetings that we held with the TNLI Project Team and on other sources and discussions, we specified a set of infrastructure options to be examined in the analysis. It was recognized that regional airports currently play a small role in civil aviation, and that this role is unlikely to grow in a world dominated by hub-and-spoke airline networks. In such a future, major airlines are likely to implement hub-and-spoke systems, resulting in traffic being concentrated at hub airports. It is unlikely that a major airline will want to create a major hub at a regional airport. Given this reasoning, the analysis did not need to consider separate cases that vary only by the number of regional airports in the infrastructure option.

An infrastructure option was, therefore, defined to be a configuration of national airport(s), where a national airport is defined as an airport that is able to accommodate large volumes of passengers and/or cargo and that can function as a hub.

The infrastructure options are defined in terms of the following key characteristics:

- The number of national airports in the Netherlands (1 or 2)
- In case there are two national airports, whether the traffic at the airports is allocated based on: type of traffic (intra-European versus intercontinental), hub-carrier, or purpose (pure cargo versus mainly passengers)
- The location of (the parts of) the airport (densely populated area; sparsely populated area; in the sea; in a lake; at the border)

In assessing the effects of an infrastructure option for a particular scenario, we assumed that all demand for air transport in that scenario would be accommodated; i.e., the national airport(s) would be sized to meet the national demands. This means that no demand would be shifted from national to regional airports because of capacity constraints (i.e., there are no "spillovers"). It also means that the physical and/or environmental capacity of an airport, in terms of aircraft movements, passenger movements, and tonnes of cargo, is not part of the description of an infrastructure option.

The fourteen primary infrastructure options we examined are described below and summarized in Figure 2.3. (The options involving two national airports each had several variants.)

Infrastructure Option N1popa

All demand is accommodated at Schiphol (located in a densely populated area). The fifth runway is assumed to be operational and facilities are enlarged as needed.

Infrastructure Option N1lake

Schiphol is closed and there is a single national airport located on an artificial island in a lake. The airport handles all types of transport and is connected to the mainland by a land bridge.

Infrastructure Option N1sea

Schiphol is closed and there is a single national airport located on an artificial island in the sea. The airport handles all types of transport and is connected to the mainland by a land bridge.

Infrastructure Option N1spa

Schiphol is closed and there is a single national airport in a sparsely populated area, non-economic center. The airport handles all types of transport.

Infrastructure Option N1border

Both Schiphol and Zaventem are closed or have a reduced role. There is a single national airport located on land somewhere on the Dutch/Belgian border. The airport handles all types of transport. For assessing this option, it is assumed that the direct economic costs and benefits are split between the Netherlands and Belgium.

Infrastructure Options RRpopa, RR1ake, and RRsea

The terminals remain in the current location at Schiphol. The runways at Schiphol with the highest noise effects are closed down. Remote runways are located at a water location, or on land. The remote runways are connected to the terminals by an underground people/cargo mover, capable of very high speeds. There is no other landside connection besides the people/cargo mover. The noisiest aircraft and all night flights are assumed to use the remote runways.

Infrastructure Options N2popa, N21ake, N2sea, and N2spa

There are two completely separate national airports in the Netherlands, which are not linked by a dedicated high speed people/cargo mover. The two national airports are connected by public transport. One of the two national airports is Schiphol. The second airport is located in the sea, in a lake, or on land (in a populated area or a sparsely populated area). Traffic is allocated between the airports based either on type of traffic (intra-European versus intercontinental) or hub-carrier (one at each airport).

Infrastructure Options N2cargo (popa and lake)

There are two completely separate national airports in the Netherlands, which are not linked by a dedicated high speed people/cargo mover. The two national airports are connected by public transport. One of the two national airports is Schiphol. The second airport is built to handle only cargo and can be built in a populated area or in a lake. All of the cargo is intercontinental cargo and only full freighters are used at the cargo airport. There is no express cargo handled at the cargo airport.

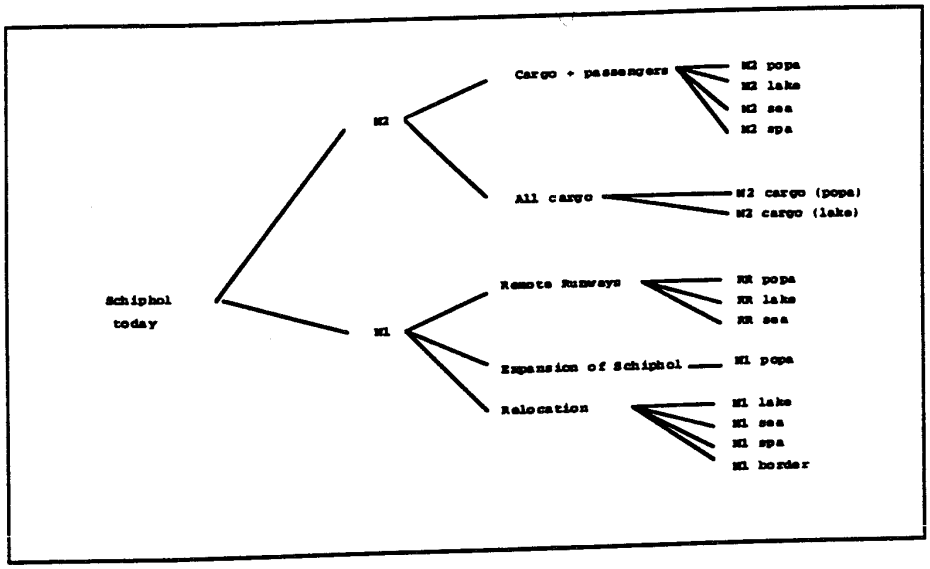

Figure 2.3-Infrastructure options examined

3. ASSESSMENT OF INFRASTRUCTURE OPTIONS

3.1 INTRODUCTION

RAND/EAC carried out an assessment of infrastructure options in support of the TNLI project. The assessment of each infrastructure option was carried out for each of the five scenarios. Each combination of a scenario and an infrastructure option was defined to be a separate *case*. The assessment of a case on the set of qualitative and quantitative criteria was done relative to a comparison point.

In the course of carrying out this assessment, two major insights were developed. First, the relative ranking of the infrastructure options on each of the performance measures was found not to differ over the scenarios. Second, the important policy conclusions about the fourteen infrastructure options could be summarized by discussing them in terms of six "themes".

The first insight is based on grouping the five scenarios into two categories: scenarios that have high growth in demand for air travel in the Netherlands, and those that do not. In the two low/no growth scenarios (Scenarios 2 and 5), the air transport demands do not exceed the existing capacity constraints at Schiphol, so there would be little need to change existing policy or build new infrastructure in order to accommodate the demand. Therefore, the results of the assessments of the infrastructure options for these two scenarios are not presented here. In the three high growth scenarios (Scenarios 1, 3, and 4), the relative performance of the infrastructure options for a given criterion remains virtually unchanged over all three scenarios. This led us to conclude that presenting the results of the assessment of infrastructure options for any one of the three high growth scenarios would be sufficient.

We grouped the assessments of infrastructure options into six themes: a land airport, remote runways, two national airports, a border airport, a water airport, and a separate cargo airport. Appendix E contains a listing of the assumptions common to the individual infrastructure options included in each of these themes.

The remainder of this section is organized as follows. First, the reference case for assessing all options -- the "Comparison

Point" -- is defined, and its purpose and use is explained. This is followed by assessments of each of the six themes.

3.2 COMPARISON POINT

The performance of each infrastructure option on each criterion is presented relative to a "Comparison Point". The purpose of the Comparison Point is to provide a "fixed point" in comparing the quantitative outputs associated with the various cases. What is most important in comparing infrastructure options on any criterion are the relative differences among them and not the absolute numbers themselves. The Comparison Point provides the mechanism for making this relative comparison. In addition, the absolute values of the effects can be difficult to interpret without a point of comparison. For example, assume that the noise indicator is 150 in Case 1 and 100 in Case 2. Without a point of comparison, these numbers are not very meaningful. However, if we know the value of the noise indicator for the aircraft mix and number of movements of the Comparison Point, we develop an understanding of how much better or worse the noise immissions are in other cases. If the noise indicator associated with the Comparison Point is 50, then one knows that the noise immissions of Case 1 are about 3 times those of the Comparison Point, and the noise immissions of Case 2 are about 2 times those of the Comparison Point.

The Comparison Point has all of the quantitative inputs and outputs associated with any other case -- transport volumes, economic effects, noise indicator, etc. The difference between the Comparison Point and the other cases is that the transport volumes are taken from the Project Mainport & Milieu Schiphol's European Renaissance/European Liberalization (ER/ELi) scenario [PMMS, 1993] and are not generated by the demand model. Like the other cases, the Comparison Point demand data were input into the project's economic effects, aircraft noise and emissions, ground access emissions, and cost models. The outputs of these models become the reference points for each criterion.

The Comparison Point is intentionally unrelated to any of the scenarios we used in the analysis, since we wanted to use the same point of comparison for all scenarios. A conscious choice was made for a set of demand figures that were for some point in the future,

rather than for the present or the past. This enabled us to include in the mix of aircraft some with seating capacities greater than any aircraft in use today. These very large aircraft are also assumed to be in use in all of the scenarios. The transport volumes used from the PMMS ER/ELi scenario for the Comparison Point are 38.6 million passenger movements, 2.1 millions tonnes of air cargo[2], and 432,000 aircraft movements.

With the exception of the demand figures, all of the model outputs presented in this report are indexed to those of the Comparison Point. In every case, the Comparison Point effects are set to 100, and the outputs from all other cases are indexed to it. Using the example presented above, the immissions for Case 1 would be shown as 300 and the immissions for Case 2 as 200.

3.3 ASSESSMENT OF INFRASTRUCTURE OPTIONS BY THEME

Assessments of the six themes (a land airport, the remote runway option, two national airports, a border location, a water location, and a separate cargo airport) are presented in the following six subsections. The six themes are not mutually exclusive. An infrastructure option can be included in more than one theme. For example, the remote runways option with the remote runways in the sea is included in both the remote runways and water location themes. Despite this overlap, the thematic structure is useful for presenting the important insights relating to the individual themes in a concise and clear manner.

3.3.1 A Land Airport

A land airport can be located in a densely or sparsely populated area. For purposes of this study, we assumed that a land airport in a densely populated area would be an expansion of Schiphol, and that an airport in a sparsely populated area would be in some location outside the Randstad.

Expanding Schiphol has many positive attributes. First, it is the least expensive of all the infrastructure options we considered for accommodating demand. Figure 3.1 shows the present value costs of all of the options. The magnitude of the cost differences between

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[2] Goods trucked under an airway bill (i.e., by "air trucking") are not included.

options ranges from moderate to very large. The differences depend on whether the infrastructure options being compared are on water or on land, and on whether single or dual national airport options are being compared.

Schiphol is conveniently located near Dutch population and economic centers. Furthermore, it is well connected to public transport, and a new HST station is included at Schiphol in the plans for the HST line going to Paris through Rotterdam, Antwerp, and Brussels.

Finally, expanding Schiphol is the least disruptive option according to several criteria. Any new infrastructure option except for the expansion of Schiphol would necessitate a redesign of airspace. Also, when compared to building an entirely new airport on a virgin site, the expansion of Schiphol is less disruptive in terms of new intrusion on natural settings and new visual intrusion. It has been a part of the landscape for 60 years, and its expansion would require less new construction than would building a completely new airport to handle the same volumes of traffic elsewhere. Hence, the additional land affected by new airport construction is less for an expanded Schiphol than for any other option.

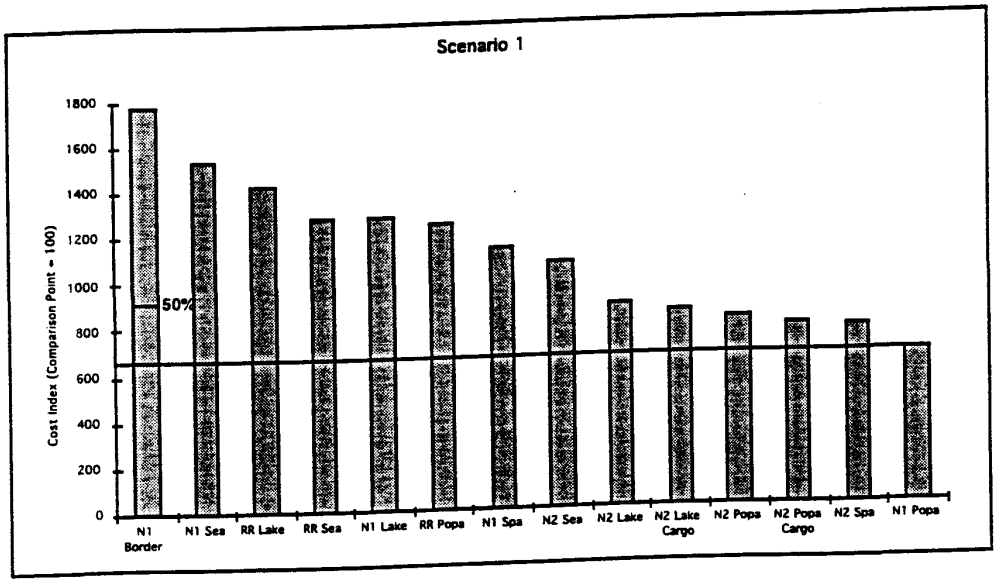

Figure 3.1-Cost index for the infrastructure options

However, an expanded Schiphol will have all the problems of a large airport located in a densely populated area. Potentially, it would expose large numbers of people to aircraft noise. The noise

immissions for this option would be about six times those of the Comparison Point. Schiphol's *vrijwaringszone*[3] would be much larger than it is today. This would restrict use of large tracts of scarce land in the Randstad. Third-party risk could also increase with an increase in aircraft movements. Finally, airport-related traffic would interfere with other road users around the airport, exacerbating an already problematic situation.

A new land airport located in a sparsely populated region of the Netherlands would lack many of the advantages of an expanded Schiphol (proximity to the Dutch population and economic centers, good connections to public transport, limited new intrusion, no immediate need for airspace redesign). It would also require a very large tract of land. The airport itself would occupy approximately 20-30 square kilometers. Additional land use around the airport would be restricted for noise and safety considerations. In Schiphol's case, the area of land within the *vrijwaringszone* is about 10 times the area occupied by the airport itself. The size of the *vrijwaringszone* around a new land airport will also encompass a tract of land much larger than the land occupied by the airport. It is unclear whether such a tract of land could be found within the Netherlands. If sufficient land were to be available, it would almost certainly still require the removal of houses or buildings.

On the positive side, a new land airport in a sparsely populated area would reduce congestion within the Randstad and would reduce noise nuisance and third-party risk to a level below that for an expanded Schiphol. This assumes that land use and zoning restrictions would be able to prevent the problem of urban sprawl around the new airport. However, urban sprawl around the airport will be a potential problem for any land location.

In summary, an airport on land will always have problems of aircraft noise and third-party risk. These problems will be lower at an airport in a sparsely populated area. However, expanding Schiphol is much less costly.

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[3] The *vrijwaringszone* is a protected zone around the airport in which no new houses may be built. Currently, this zone is defined only for Schiphol. The purpose of this zone is to ensure that adequate spatial quality is maintained. Spatial quality consists of two components: spatial and environmental. The spatial aspects are openness, flexibility, and sustainability. The environmental aspects are noise and third party risk.

3.3.2 Remote Runways At A Water Location

As was described in Sec. 2, the remote runway option consists of Schiphol plus a set of runways at a distant location that are connected to Schiphol by a high speed people and cargo mover. This option has many positive aspects. It preserves most of the advantages of a single airport system, since the remote runways along with the terminals and other landside facilities would be operated as a single airport system. Additionally, the remote runway option retains the advantages of Schiphol's location: good connections to public transport, a HST station at the airport, and proximity to the Dutch population and economic centers. Finally, it makes use of Schiphol's existing infrastructure.

The remote runway option at a water location has additional advantages. It avoids the problem of urban sprawl and commercial development around the runways, factors that could constrain future growth of the airport. And, if there were a landside connection to the mainland (which we did not consider) and some aviation activities (e.g., cargo handling) were located at a remote satellite facility, the remote runway option might be a way to stimulate regional economic development.

This option would also dramatically reduce the numbers of people who would be potentially exposed to aircraft noise and to third-party risk. Figure 3.2 shows that a significant amount of the noise load can be shifted away from Schiphol by using remote runways built in the water. The population exposed to unpleasant kerosene odors and aircraft emissions around the airport would also be reduced.

However, the remote runway option at a water location has some potential drawbacks. The success of this option critically depends on the availability of people/cargo mover technology that would allow connection times at competing airports to be matched. Doing so would require a high speed people/cargo mover capable of transporting large numbers of people quickly and reliably. Such a high speed people/cargo mover is expensive. In fact, we estimate that the people/cargo mover would account for 50 to 60 percent of the total cost of this option. Also, building runways at a water location could create new ecological problems. Because of their water location, these runways could be more vulnerable to the weather than

runways at a land-based airport. Finally, the remote runway option would not solve the traffic problems associated with an expanded Schiphol: airport-related traffic would still interfere with other road users.

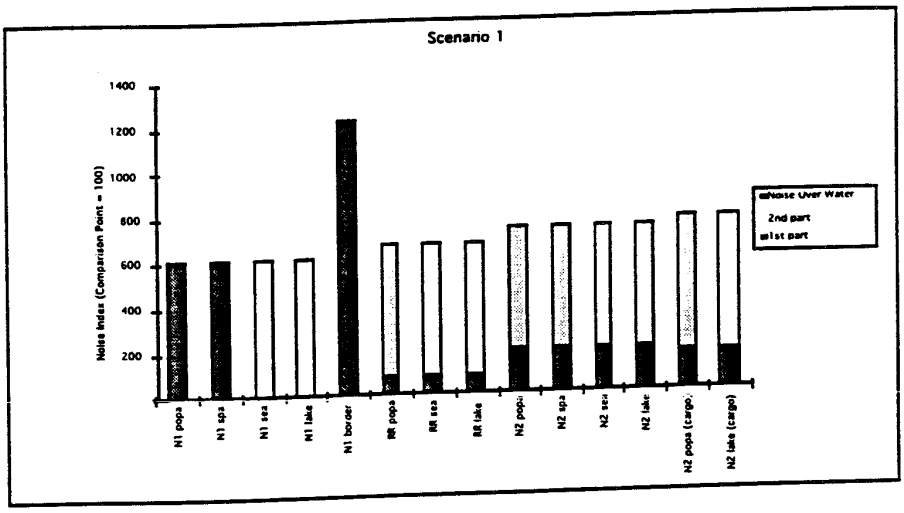

Figure 3.2-Noise index for the infrastructure options

In summary, the remote runway option at a water location combines the advantages of an expanded Schiphol with the advantages of an airport in the water. However, the success of this option depends to a large extent on the availability and use of a fast, reliable, and high-capacity people/cargo mover. Such technology is expensive. The costs of constructing this high speed link between the terminals and runways is the largest cost component of this option. Thus, the issue of the high speed people/cargo mover must be examined more closely.

3.3.3 Two National Airports

One of the differences between a two national airport option and a single national airport option is in the overall mix of aircraft used to meet the passenger and cargo demands. The different aircraft mix means that the total economic and environmental effects for a two national airport option will be different from these effects for a single national airport handling the same number of passengers and cargo.

If a two national airport option were to be successful, there could be slightly higher direct and total employment for the two

airport system compared to a single national airport accommodating the same traffic volume as the two airports combined (see Fig. 3.3). The new airport might also stimulate regional economic development.

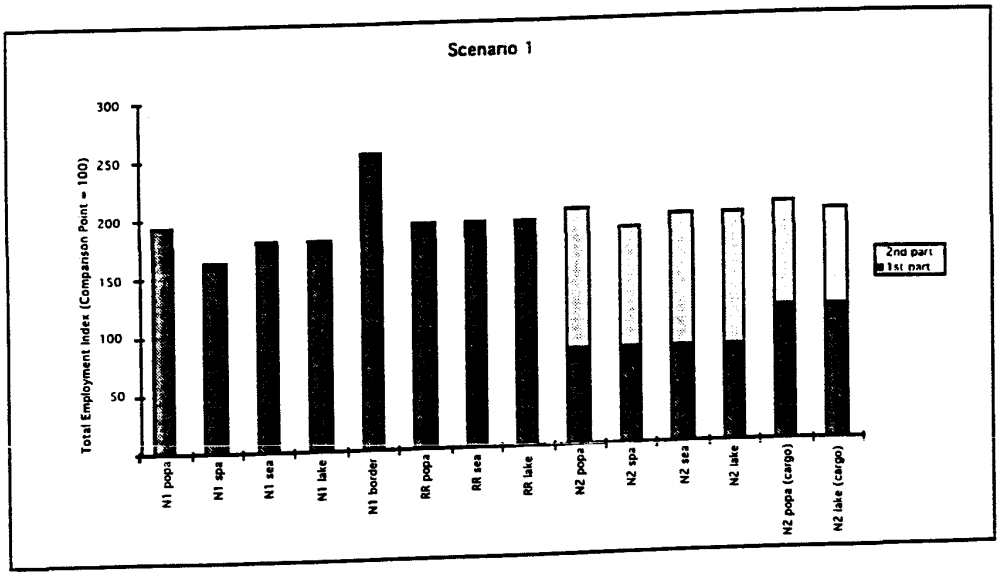

Figure 3.3-Total employment index for the infrastructure options

Due to differences in aircraft mix, the total aircraft emissions and noise immissions of the two airport system can be higher than at a single, larger airport. Nevertheless, the noise, local emissions, and surface congestion problems at each of the two individual airports may be smaller than if all traffic were handled at a single national airport. Figure 3.4 shows the split of the noise and local emissions for the two airport option if one airport was exclusively used to accommodate intercontinental (ICA) traffic, and the other was used to accommodate intra-European traffic.

An HST station at the second national airport would require a change in current plans. If it does not have an HST station, passengers at the second airport would not be able to use the HST with the same level of convenience as passengers using Schiphol. Finally, the two national airport option is less efficient than a single airport: more runways and land would be needed in a two airport system than at a single airport to accommodate the same amount of passenger and cargo demand.

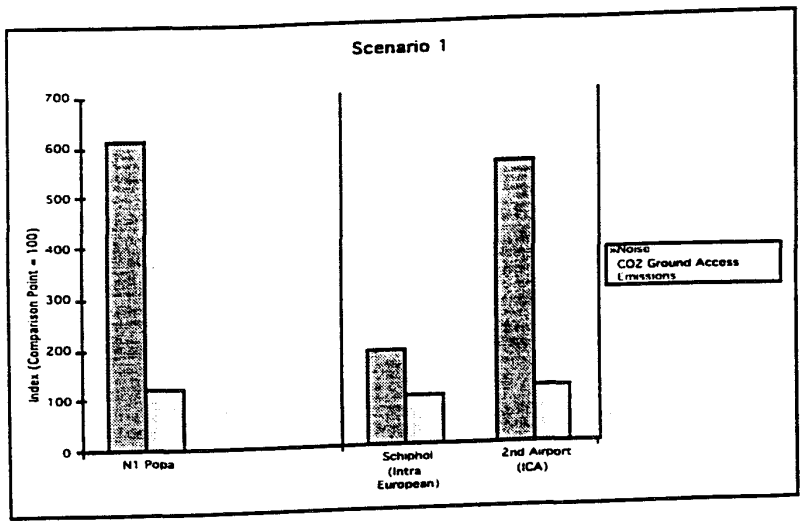

Figure 3.4-Noise immissions and local emissions in the two national airports option.

Based on our research and interviews of experts in airline and airport operations, we found that there are several factors that could affect the success of a two airport system in the Netherlands. These factors are outside the direct control of the Dutch government. First, very high levels of demand would be needed to sustain two national airports. This level of demand could be provided if two major airlines decided to locate their hubs in the Netherlands, or if there were a lack of capacity at competing European airports. Second, the experience of airports in Paris, London, and Washington D.C. illustrates the need for government involvement in the operation of a two-airport system. Government involvement is needed because, as de Neufville explains [de Neufville, 1995], without government involvement airlines would tend to concentrate their operations at one airport in a multi-airport system. And, even with government involvement, airline cooperation would be needed to divide traffic between the two national airports.

Current trends and developments are at odds with the requirements for a successful two national airport system in the Netherlands. Large, new airports are currently being planned for Berlin and Paris. Other European airports have plans to expand capacity as well. A review of infrastructure developments at 25 Northern European airports by SH&E Research indicates that 24 of them have plans to expand passenger terminal space, and nine have plans for new runway developments [SH&E Research, 1996]. It is also

unlikely that two large airlines would locate their hubs in a small country like the Netherlands with a relatively small catchment area. Finally, the role of the government in civil aviation is declining. Given all this, it is difficult to imagine that airlines with hub-and-spoke networks will agree to split their operations over two hubs.

In summary, our assessment of a two national airport option is dominated by the fact that its success is dependent on factors that are outside the direct control of the Dutch government and that are at odds with current civil aviation trends. If hub-and-spoke networks do dominate in the future, the tendency for airlines to concentrate operations at a single airport makes it unlikely that two national airports can be operated successfully in the Netherlands.

3.3.4 Border Location

Assuming that the necessary cooperation between governments is forthcoming, an airport on the Dutch/Belgian border operated jointly by the Netherlands and Belgium would have a very strong competitive position in Europe. Of course, this option would require that both Schiphol and Zaventem be closed or have reduced roles compared to the current situation. If this happens, the border airport would be somewhat more centrally located than Schiphol currently is, it would have a very large catchment area, and competition between Schiphol and Zaventem would be reduced or eliminated.

The border airport would be significantly larger than any other airport examined in this analysis. This is due to the airport's catchment area, which includes the Netherlands and Belgium. The estimated passenger volumes are 15-55 percent higher, and cargo volumes about 35 percent higher, than the volumes handled by the other infrastructure options analyzed. The number of aircraft movements would also be significantly higher for the border option.

The border airport option will require close Dutch and Belgian cooperation. Important areas on which agreements must be negotiated are the division of costs and employment. An airport on the border is the largest and thus the most expensive of the options considered in this analysis. However, we assumed that the costs of the airport would be shared by the Netherlands and Belgium. If they are shared 50%-50%, the cost of this option is comparable with other two-airport

options. However, if the total employment is also split 50%-50%, Dutch employment would be less for this option than for the other single-airport options. Thus, the large traffic volumes do not generate comparably large employment benefits for the Netherlands.

In addition, the border airport will have the problems of any very large airport on land: aircraft noise immissions, local aircraft emissions, third-party risk, and urban sprawl and encroachment. Unlike costs and employment, these effects cannot be split 50%-50% between the Netherlands and Belgium. Furthermore, there would not be an HST station at the border airport without a change in current plans.

Another potential problem faced by the border airport option is that only one hub carrier is likely to be able to operate at the combined airport. This means that one of the two main carriers currently based at Schiphol and Zaventem may not survive, or that the two will combine (e.g., through a merger, takeover, or alliance). Currently, Chicago's O'Hare International Airport, the world's busiest, is the only airport in the world that serves as a hub for two major airlines. Even London's Heathrow Airport, the largest in Europe, serves as a hub for only one carrier, British Airways (BA). The second largest carrier, British Midlands, is not a hub carrier and does not compete directly with BA. Hence, the fact that there is but one airport in the world that serves as a hub for two major airlines suggests that this may be a difficult or non-viable situation.

In summary, a border location improves the competitive position of a Dutch national airport, but offers little else. First, close cooperation between the Netherlands and Belgium is necessary for this option to succeed. Second, historical evidence suggests that it is unlikely that both a Dutch and Belgian carrier would operate hubs at the same airport. Third, the airport would lead to serious problems of noise, local emissions, and third-party risk if it were built on land. If the airport were located in water, these problems would be reduced or eliminated, improving the attractiveness of this option. A water location would be expensive, but the costs would be shared.

3.3.5 A Water Airport

A water airport located in a lake or the sea would drastically reduce or fully eliminate the problems associated with third-party risk, aircraft noise, and local emissions. It would also eliminate the problem of urban sprawl around the runways that might constrain future airport expansion. But, if there were a landside connection to the mainland (which we did not consider), a water airport might be a way to stimulate regional economic development.

Figure 3.5 shows how noise and local emissions could be reduced by a sea location. The noise bars for the sea location have been left white to indicate that, while noise is emitted, it would probably not cause much nuisance or annoyance.

The major drawback of building a new airport at a water location is the cost of doing so. Building an airport at a water location is significantly more expensive than building a comparable airport at a land location.

A water location is also more vulnerable to the weather than a land location. Also, because airport employees cannot live close to the airport, their commuting times would increase. This has negative repercussions for the environment as well. In addition, an airport at a water location can cause new ecological problems. Finally, locating an HST station near a water location would require a change in current plans.

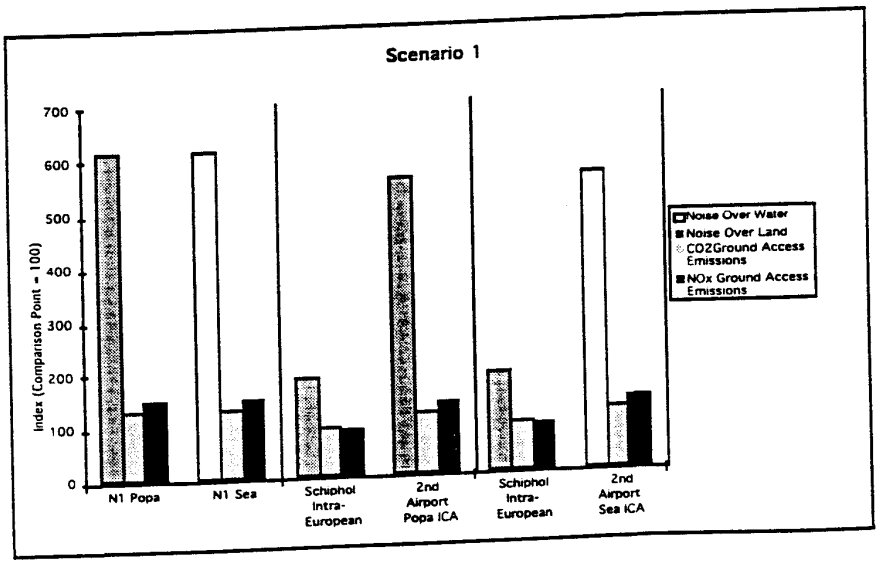

Figure 3.5-Noise immissions and local emissions at an airport in a water location.

In summary, a water location has the potential to completely eliminate the problems associated with aircraft noise and third-party risk. However, the scale of such construction would cause new environmental problems. Such an airport would also be very expensive. Thus, the reasonableness of such an option depends on the value attached by society to eliminating aircraft noise and third-party risk. Also, if no land is available for a new airport, an airport in the sea or lake may be the only viable option.

3.3.6 A Separate Cargo Airport

A successful two national airport system with an all-cargo airport would require changes in how air cargo is transported. The flows of passengers and cargo would have to be separated. This means that airlines would have to stop carrying cargo on scheduled passenger flights. Instead, most air cargo would be transported on full-freighter aircraft flying into and out of the all-cargo airport. In addition to the separation of passenger and cargo flows, the air cargo industry would have to undergo consolidation and concentration. Finally, the volume of cargo that would be needed to support the operation of an all-cargo airport is several times higher than the volume of cargo currently handled at Schiphol. While none of the changes described above is impossible, the magnitude of these changes is so large that their occurrence in the next 25-30 years is unlikely.

A successful air cargo airport would require a large number of night flights. This could be problematic, since the resulting noise nuisance could be great. However, if the all-cargo airport were at a water location, the noise problem associated with night flights would be reduced or eliminated.

The all cargo airport option would result in a large increase in noise immissions and local emissions (see Fig. 3.2). There would be only a small number of flights at an all-cargo airport because the aircraft are full freighters. However, the flights would be made by large aircraft and many would fly at night. Large aircraft flying at night generate a large amount of noise immissions, and these immissions can be expected to exceed the immissions at a single airport handling the same volume of cargo but not using only full

freighters. So, the total immissions would probably exceed those of the single airport options. Also, as with the other two-airport options, the total ground access emissions for the two airports combined would probably be larger than the emissions at a single airport.

In terms of costs and economic effects, there are no significant differences between the all-cargo airport option and other two-airport options. An all-cargo airport is less expensive than a second airport handling both passengers and cargo. However, the all-cargo system requires a larger passenger airport. Thus the cost of a two-airport system in which one of the airports is an all-cargo airport is about the same as the cost of a two-airport system in which both airports handle both passengers and cargo. The total direct and indirect employment in a two-airport system with an all-cargo airport is about the same as in the other two-airport systems.

In summary, a separate air cargo airport requires big changes in how air cargo is transported to make it successful. Furthermore, it would increase aircraft noise and local emissions, but would not provide significant economic benefits or reduced costs.

4. CONCLUSIONS

In this project, a broad range of infrastructure options were compared on consistent and logical grounds. In a sense, it was a screening project. It began with a wide variety of possible changes in the structure of the civil aviation system that might occur in the future, and a wide variety of possible infrastructure options for accommodating the demands for air transport that might occur given those changes. We collapsed the changes into five scenarios, which we believe are likely to span the space of possible futures. We concluded that regional airports are unlikely to play a major role in commercial civil aviation in the future, so we focused on infrastructure options for one or two national airports. We found that in some of the future worlds the capacity constraints at Schiphol Airport would not be exceeded, so the prevailing policy of the government would not have to be changed. For the rest of the future worlds (worlds in which there is high growth in demand), we reached some general conclusions about the infrastructure options available to policymakers in the Netherlands that would enable the demand to be accommodated.

The overarching conclusion we reached is that, in comparing infrastructure options for handling high demands, there is no single infrastructure option that dominates all of the others. Each of the options we examined has some important positive attributes and some major negative attributes.

- Water location options (including a new national airport to replace Schiphol, a second national airport, or remote runways connected to Schiphol) are best for reducing or eliminating noise, local emissions, and third party risk. But an airport at a water location is always more expensive than a similar airport located on land, would create new ecological problems, and would be vulnerable to the weather

- Expanding Schiphol is the least expensive option. It is also the least disruptive option according to several criteria (e.g., new intrusion on natural settings and new visual intrusion). But it has all the problems of a large airport in a densely populated area (e.g., noise, third party risk, and airport-related traffic congestion).

- Building remote runways at a water location has most of the advantages and disadvantages of a new airport at a water location. But, the high speed people/cargo mover that this option requires is expensive and must be reliable. In

addition, this option would not relieve airport-related traffic congestion around Schiphol.

- A border location is best in terms of its competitive position, since it increases the size of the catchment area and it has a better geographic location. But it is a costly and environmentally damaging option.

- A second national airport would cost less to build than a new national airport and would distribute the negative effects. But its success would depend on factors outside the control of the Dutch government.

- A separate cargo airport would cost less than a second national airport and would reduce the noise around Schiphol. But, it would require big changes in how air cargo is transported to make it successful, and those changes are beyond the control of the Dutch government.

The analysis provides information on the effects of a broad range of civil aviation infrastructure options and makes it possible to compare the options on a consistent and logical basis. Preferences among the options depend on how important the various criteria are to the various stakeholders and policymakers; i.e., how they value the positive attributes of an option compared to the negative attributes.

APPENDIX A

PARTICIPANTS IN THE ROUND TABLE MEETINGS

Mr. J.M. Abbink, Luchthaven Lelystad
Mr. H. Bakker, Stichting Rentmeesters
Mr. J.J.A. van Bennekom, Rotterdam Airport B.V.
Mr. M. van Berckel, Air Holland
Mr. W.J. Berg, Dorpsraad Badhoevedorp
Mr. J. den Besten, Fokker
Mr. F. Bisschop, Air Transport Association Netherlands
Mr. R. Bleumink, Martinair
Mr. B. Bochove, OR Martinair
Mr. G.G.M. Boosten, Amsterdam Airport Schiphol
Mr. H. Bos, Vliegveld Welschap
Mr. L. Damen, Belangenvereniging Almere-Hout
Mr. W. Duyvendak, Milieudefensie
Mr. I. Ebbers, Dorpsraad Badhoevedorp
Mr. J. Fransen, Stichting Natuur en Milieu
Mr. W.J. van Grondelle, Stichting Natuur en Milieu
Mrs. P.R. Goudsmit, Artsenwerkgroep Zuid-Limburg
Mr. R.B. de Haan, Kamer van Koophandel Amsterdam
Mr. R. Hijdra, Natuurmonumenten
Mr. L. van der Hoeven, Nederlandse Spoorwegen
Mr. T. Huigen, Canon Europe
Mr. Th.J. Hulsebosch, Kamer van Koophandel Haarlem
Mr. J. Jansonius, VNO/NCW
Mr. H. Jolles, Dorpsraad Badhoevedorp
Ir. H.J. Kamphuis, Dutch Air Traffic Control
Mr. J.J.W. Kerckhoff, KLM Royal Dutch Airlines
Mr. A. Kilsdonk, Government Travel
Mrs. F. van der Klugt, Nederlandse Stichting Geluidhinder
Mr. H. Klumper, Directorate General of Civil Aviation, Aviation Inspection
Mr. J. Kolmer, Yamaha Motor Distribution
Mr. J. Krul, Amsterdam Airport Schiphol
Mr. J. van Kuijk, Provincie Flevoland
Mr. P. Langeweg, ANWB
Mr. H.J. Licher, Provincie Flevoland
Mr. B. Linders, Commissie Geluidhinder Schiphol
Mr. P. Loos, Provincie Flevoland
Mr. R. van Lotringen, Vereniging Onwonenden Luchthaven Eelde
Mr. M. van de Luit, Stichting Natuur en Milieu
Mr. R. van der Maaten, KLM Royal Dutch Airlines
Gen. G.F.A. Macco, Royal Air Force
Mr. C. Meijer, Comité Schoon Zeewolde
Mrs. M.J.H. van Mierlo-Biezenaar, Vereniging Belangenbehartiging Omwonenden Welschap
Mr. H. Ooms, Dutch Air Traffic Control
Mr. W. Peppelman, OR Amsterdam Airport Schiphol
Mr. W. Philippe, Eurocontrol
Mr. B. Radstaak, Nederland Distributieland
Mr. J. Rensing, Randstadoverleg Luchtvaart
Mr. B. Roos, Stichting Rentmeesters
Mr. A.B. Sakkers, Provincie Groningen
Mr. Th. Schmitz, ANVR

Mrs. J. Smeets, FNV Vervoersbond, sectie Luchtvaart
Mr. C. Smit, Schiphol Area Development Company
Mr. J. Steenhart, ING Groep
Mr. R. Sturm, Amsterdam Airport Schiphol
Mr. J. Suyker, Tandem
Mr. E.H.P. Swarte, Stichting Centraal Comité Anti-Bulderbaan
Mr. W. Trommels, Schiphol Area Development Company
Mr. R. Umans, Nederlandse Spoorwegen
Ktz. M.D. Valentijn, Royal Navy
Mrs. M. in 't Veld, Belangenvereniging Almere-Hout
Mr. E. Verweij, OR Amsterdam Airport Schiphol
Mr. R. Visser, Directorate General of Civil Aviation, Aviation Inspection
Mr. W. Vooren, Directorate General of Civil Aviation, Aviation Inspection
Mr. F. van der Werff, Groningen Airport Eelde
Mr. H. Wever, Milieufederatie Flevoland
Mr. F. Weygertse, De Rijk
Mr. W. Willems, Vereniging Geen Uitbreiding Vliegveld Beek
Mr. J. Zuidgeest, Stichting Luchtvaarthinder

APPENDIX B

PERSONS INTERVIEWED

Ir. J.W. van Ammers, DHV Environment & Infrastructure
Ir. A.J. Baayen, Ministry of Housing, Spatial Planning and Environment, Directorate General for Environmental Protection
Mr. D. Benschop, Corporate Communications, Amsterdam Airport Schiphol
Prof. J. Berechman, Faculty of Social Sciences, Tel Aviv University
Mr. F.S. Bisschop, Amsterdam Airport Schiphol
Drs. ing. P.M. Blok, Bureau voor Economische Argumentatie BV
Mr. G.G.M. Boosten, Business Development & Planning, Amsterdam Airport Schiphol
Mr. K. den Braven, Ministry of Transport, Public Works and Water Management, Directorate General of Civil Aviation, Air Transport and Infrastructure Policy Directorate
Ir. H.A. Brockmeier, Netherlands Airport Consultants BV
Mr. I. Dale, British Airways
Mr. A. McDermid, Airport Strategy, British Airport Authority
Mr. J.H. Enter, Ministry of Housing, Spatial Planning and Environment, National Spatial Planning Bureau
Prof. dr. A. Faludi, University of Amsterdam, SC Metropolitan Environment
Mr. J. Fransen, Stichting Natuur en Milieu
Mr. J. Graafland, Aerius Institute for Traffic- and Transport Economics, University of Amsterdam
Ir. J. Griep, Ministry of Transport, Public Works and Water Management, Directorate General of Transport, Projectbureau Hogesnelheidsspoorlijn
Mr. H. de Groot, Ministry of Transport, Public Works and Water Management, Directorate General of Civil Aviation
Mr. P. Haanappel, International Airline Transport Association
Drs. Ph.M. van der Haer, Ministry of Transport, Public Works and Water Management, Directorate General of Civil Aviation, Air Transport and Infrastructure Policy Directorate
Mr. Th.H.M. Hagenberg, National Aerospace Laboratory (NLR)
Mr. M. O'Hanrahan, Institute of Air Transport
Ir. G.L. Hondius, Netherlands Airport Consultants BV
Mrs. B. Houben, British Midland
Ir. M.V. Julius, Netherlands Airport Consultants BV
Ir. F. Kamerling, Netherlands Airport Consultants BV
Mr. Kamphorst, Gemeente Amsterdam
Ir. H.J. Kamphuis, Dutch Air Traffic Control
Mr. J.W. Kerckhoff, KLM Royal Dutch Airlines, Corporate Strategy and Planning
Dr. ir. M. Kerkhof, Ministry of Transport, Public Works and Water Management, Directorate General of Public Works and Water Management, Transport Research Centre
Ir. G.J. Keur, Amsterdam Airport Schiphol
Mr. A.J. Koppert, Ministry of Transport, Public Works and Water Management, Directorate General of Civil Aviation
mr. P. Kraaijeveld, Amsterdam Airport Schiphol
Mr. M.A. Kraan, Member of the Air Navigation Commission of the International Civil Aviation Organization
Prof. dr. J.G. Lambooy, University of Amsterdam
Mr. J. Leemhuis, Global Business Network Europe

Mr. J. van Lieshout, Ministry of Transport, Public Works and Water Management, Directorate General of Civil Aviation
Mr. P. Luttik, Arthur D. Little International, Inc.
Mr. B. Miaillier, Eurocontrol
Prof. R. de Neufville, Massachusetts Institute of Technology
Mr. M. Norder, Ministry of Housing, Spatial Planning and Environment
Mrs. M. Ohm, Ministry of Transport, Public Works and Water Management
Mr. H. Ooms, Air Traffic Control Schiphol
Prof. ir. J. Pavaux, Institute of Air Transport
Mr. B. Korsgaard Pedersen, Copenhagen Airport
Ir. A.F.A. Pieterse, Ministry of Transport, Public Works and Water Management, Directorate General of Civil Aviation, Aeronautical Inspection Directorate
Ir. A.H. Polderman, Ministry of Transport, Public Works and Water Management, Directorate General of Public Works and Water Management, Transport Research Centre
Prof. dr. P. Rietveld, VU Amsterdam, Faculty of Economics and Econometrics
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Ir. H.J. Simonson, Copenhagen Airport
Mr. H.N.J. Smits, Managing Director, Schiphol Airport
Dr. G. Stadler, Austrian Civil Aviation Authority, Federal Ministry of Public Economy and Transport
Mr. mr. J. Teders, Ministry of Transport, Public Works and Water Management
Mr. Ch. Vandenberghe, Eurocontrol
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Ing. H.B. Waller, DHV Environment & Infrastructure
Mr. L. van de Weijer, KLM Royal Dutch Airlines, Cargo Division
Prof. drs. J.G. de Wit, Ministry of Transport, Public Works and Water Management, Directorate General of Civil Aviation, Air Transport and Infrastructure Policy Directorate

APPENDIX C

ASSUMPTIONS IN MODELS

ASSUMPTIONS IN DEMAND MODEL
The model estimates worldwide demand for passenger and cargo air transport to, from, and through the Netherlands. We used the year 2025 in making the estimates for the various scenarios.

Model Structure
- Interaction between supply and demand (feedback) not modeled.
  - effects of constraints at Schiphol not modeled.
- Effect of Dutch airport location on demand to use airport not modeled.
- Effect of Dutch airport "attractiveness" not explicitly modeled.

Europe
- Adequate capacity exists at all European airports.
- There is no congestion or saturation at any European airport or in European airspace.

Airlines
- Airline behavior modeled to the following extent:
  - scenario-related assumptions about number and locations of hubs in Europe.
  - hub/home carrier has a certain proportion of the traffic carried at an airport.

Cargo
- Trucked cargo is excluded from cargo calculations
- With the exception of the all-cargo airport, cargo is assumed to be carried by passenger aircraft (in bellies and combi-aircraft). If the cargo volume is more than what can be carried by passenger aircraft, the extra cargo was assumed to be carried in full-freighters.

Charter Traffic
- Charter traffic is treated as scheduled traffic.

Infrastructure Options
- The remote runway option was assumed to operate like a single national airport.
  - The impact of different connection times on demands at the airport were not explored.
- The border airport was assumed to be located on land on the border with Belgium. The catchment area of that airport is the Netherlands and Belgium combined.
- Two national airport options:
  - No significant connecting traffic between airports.
  - No dedicated HST is assumed to operate between the two airports.
  - Traffic was allocated using one of the three following rules
    1. *Intercontinental (ICA)/ Intra-European split*: Intercontinental traffic originating (terminating) within the Dutch airport's catchment area or connecting at a Dutch airport travels via the ICA airport. All other

Intra-European traffic travels via the airport designated as Intra-European.

2. *Two hubs*: Travel to, from, or through the Dutch airport's catchment area is split 50%-50% over the two hubs.
3. *All-cargo hub*: One airport handles exclusively passenger traffic, the other exclusively cargo.

Fleet Mix

- Fleet mixes were developed in conjunction with experts in aircraft technology and aircraft economics. The fleet mix was defined by seating class, and included aircraft from 16 seats to over 800 seats. Zeppelins and hot-air balloons were determined to be not a major factor in the hub-and-spoke systems assumed in the scenarios.

Substitution

- Substitution by High-Speed Train (HST) taken into account.
  - In Scenarios 1, 2, and 3, 100% substitution is assumed on the London-Paris-Brussels-Cologne HST network.
  - In Scenarios 4 and 5, 90% of all Intra-European air travel is substituted by HST due to environmental concerns.

ASSUMPTIONS IN ECONOMICS MODEL (LEDA)

The Economics model (LEDA) estimates future national effects of the infrastructure options in terms of employment, gross value-added, land use requirements, and demand for landside access.

The model does not determine the macroeconomic effects of the infrastructure investments, only project effects.

The year 2025+ was assumed.

Employment

- Direct and indirect (backward, forward, and formation) employment is estimated for national airports; direct and backward employment is estimated for regional airports.
- Transport volumes, airport location, airport function, level of European integration, the competitive position of Dutch airports within Europe, and labor productivity developments affect the level of employment.
- Regional and local employment effects are not estimated.

Gross Value-Added

- The gross value-added of all direct and indirect aviation-related employment for the national and regional airports is estimated.

Land-Use Requirements

- The net land use (in hectares) of company and office activities, and the gross floor demand (in square meters) of retail/hotels, restaurants and cafes (horeca)/ conferences and fairs, and international tourism activities related to direct and indirect employment are estimated.

Demand for Landside Access

- The peak demands for road capacity, public transport, and parking space related to direct employee, passenger, and cargo transport are estimated.
  - Modal split, and parking factors are consistent with future targets set for Schiphol employees and passengers.
- The model does not determine if the existing road and rail infrastructure is sufficient to meet the estimated demand.

ASSUMPTIONS IN NOISE MODEL

- The model estimates aircraft noise immissions in the vicinity of each airport. Given a mix of aircraft split over day and night operations, the model calculates a nose indicator for the specified aircraft activity.
- The model simplifies location-specific information usually needed for a noise contour to a single runway, with a standard set arrival and departure routes for each airport.
- Night operations are penalized.
- The model uses the LDN 70 dB(A) calculation to calculate the indicator.
- The noise indicator does not calculate a noise contour, the number of houses in the noise contour, or the number of people annoyed or highly annoyed by the aircraft noise (since the infrastructure options are not site-specific).
- Noise reductions were estimated for each representative aircraft type.
- For the remote runway infrastructure option, the two noisiest categories of aircraft, plus all night flights, were assumed to operate at the remote runways.

ASSUMPTIONS IN AIRCRAFT EMISSIONS MODEL

- The model estimates total emissions for a number of exhaust gasses during the approach, landing, taxi, take-off, and climb cycle of the total air traffic below 10,000 feet or (3,000 meters) of altitude.
- The emissions calculated are for the total annual emissions of all aircraft movements.
- Emission reductions are estimated for each representative aircraft type.
- Emissions for the entire flight from origin to destination are not calculated.

ASSUMPTIONS IN COST MODEL

- Costs are accounting rather than opportunity costs.
- The costs estimated are for an airport designed to accommodate peak-hour passenger, cargo, and aircraft movements. The model assumes that the peaks will be more smoothed than they are today, resulting in a more efficient use of the airport infrastructure. The model makes no assumption about the cost of smoothing the peaks.
- Certain costs associate with airport infrastructure construction are not taken into account, due to the lack of data or site-specific information. These include:
  - Ground preparation and cleanup of waste sites.
  - Noise insulation.
  - Procedural requirements and landscape damage compensation.
  - Interference with military aircraft operations.
  - Modifications to national air traffic control systems.
  - Transfer of facilities and operations from Schiphol to a new national airport.
  - Congestion.
- Two national airport options:
  - There is no dedicated transport link between the two airports.
  - One of the two airports is assumed to be Schiphol.

- Schiphol:
  - Infrastructure options that include Schiphol assume that approved expansions (e.g. the fifth runway) have already been implemented.
  - Infrastructure options that include Schiphol assume that passenger, cargo, and aircraft movement capacities can be increased, if needed, above the current constrained levels.
- Ground access infrastructure costs of connecting the airport to existing road and rail infrastructure are included. Costs of expanding of the existing road and rail network to accommodate travel to and from the airport are not included.
- The investment costs of the HST are excluded. (The cost of the high-speed people/cargo mover in the remote runway option is included.)
- Cross-wind runways are assumed for the sea and lake airports.

ASSUMPTIONS IN GROUND ACCESS EMISSIONS MODEL

- The model estimates the emissions generated by O/D passengers, employees, and cargo traveling to and from the airport within 20 km of the airport on a yearly basis.
- An average distance of 25 kilometers per trip within 20 km of the airport is traveled.
- Data from the CBS and the PMMS study are used to estimate the emission factors for the year 2015. No further reduction of the emission factors are assumed for the year 2025+.
- The emission factors of the HST are the same as the emission factors of a regular train.
- The high speed people/cargo mover connecting the remote runways and Schiphol is a non-polluting mode of transport.

APPENDIX D

QUANTITATIVE AND QUALITATIVE CRITERIA USED IN THE ANALYSIS

Category/Impact Measure	Quantitative/ Qualitative
System Aspects	
• Interference with use of airspace for military or other national security purposes.	• Qualitative
• Average connection time	• Qualitative
• Effects of weather	• Qualitative
• Potential for future expansion, or the ability to accommodate new aircraft technologies	• Qualitative
• Ability to add capacity to accommodate future growth in demand, e.g. add runways or terminals	• Qualitative
Mobility Aspects	
• Substitution:	
– number of passengers taking high speed train	• Quantitative
	• Qualitative
• Integration with high speed train network, conventional trains, and trans-European highway network.	• Qualitative
• Interference of airport-related traffic with local non-airport-related transportation activities.	• Qualitative
• Convenience of location for passengers, cargo, and employees.	• Qualitative
Economic Aspects	
• Employment due to activity at Dutch national and regional airports, in the categories of direct and indirect (backward, forward, and formation linkages) employment.	• Quantitative
• Gross value added for the categories of aviation-related employment mentioned above.	• Quantitative
• Regional economic developement	• Qualitative
Environmental Aspects	
• Emissions:	
– Total exhaust emissions of the landing and takeoff cycle (LTO) of all flights, extended up to 10,000 ft.	• Quantitative
– Emissions nuisance from other traffic at the airport	• Qualitative
– Emissions from employee, passenger and cargo traffic to/from airport	• Quantitative
• Noise:	
– Indicator for the ground surface within the noise load contour of LDN 70 dB(A).	• Quantitative
– Population affected by noise	• Qualitative

• Safety: – Third-party risk • Intrusion on natural settings • Effects on flora, fauna, and vegetation • Visual intrusion	• Qualitative • Qualitative • Qualitative • Qualitative

Spatial Aspects
• Land needed for the infrastructure option
• Size of the *vrijwaringszone* around the airport(s)
• For an area of approximately 20 km around national airport(s):
  – net land use demand (hectares) for company activities in industry, transport, and distribution sectors
  – net land use demand (hectares) for office space by government, businesses and other services
  – gross floor demand (square meters) by retail trade and hotels, restaurants and cafes
• The potential benefits of an airport's land in case the airport is closed or moved to another location.
• Land becoming available for noise-sensitive functions, based on size of the '*vrijwaringszone*' in case the airport is closed or moved to another location (square meters or hectares).
	• Quantitative
	• Qualitative
	• Quantitative
	• Quantitative
	• Quantitative
	• Qualitative
	• Qualitative

Costs of Infrastructure Options • Pre-construction costs; categories include cost of land (if airport on land), cost of creating artificial island (if in water), project preparation, engineering and design. • Construction costs; categories include runways, taxiways, aprons, buildings, ATM system, and landing systems. • Additional Costs; categories include road and rail connections to existing transport infrastructure, connection of water-based airport to land. • Costs of moving operations from Schiphol to new airport. • Incremental costs of ATC. • Compensation costs of moving people/insulation of buildings. • Costs of expanding infrastructure for ground access.	• Quantitative • Quantitative • Quantitative • Qualitative • Qualitative • Qualitative • Qualitative

APPENDIX E

ASSUMPTIONS ABOUT INFRASTRUCTURE OPTION THEMES

Land Airport
- A land airport in a densely populated area is an expansion of Schiphol.
  - All demand is accommodated at Schiphol.
  - The fifth runway is assumed to be in operation.
  - Facilities are enlarged as needed.
- A land airport in a sparsely populated area is located outside the Randstad.
  - A new airport is built.

Remote runways
- Remote runways built at a water or land location.
- Terminals will remain in current location at Schiphol.
- Remote runways will be connected to terminals by an underground people/cargo mover capable of very high speeds.
- Runways at Schiphol with the highest noise effect will be closed down.
- There will be no other landside connection for the remote runways besides the people/cargo mover.
- The noisiest aircraft will be directed to use the remote runways.
- All night flights will use the remote runways.

Two national airports
- Two completely separate airports in the Netherlands.
  - One of the two national airports is Schiphol.
  - The second airport is located in the sea, in a lake, or on land.
- The airports are not linked by a dedicated high speed people mover.
- Connections between airports are made using public transport.
- Traffic at the airports is allocated based on type of traffic (intercontinental/intra-European), hub carrier, or purpose (passenger, cargo).

Border location
- Both Schiphol and Zaventem are closed or have a reduced role.
- The new airport is located on land, somewhere on the Dutch/Belgian border.
- The direct economic costs and benefits are split equally between the Netherlands and Belgium.

Water location (sea or lake)
- Built on an artificial island.
- Connected to mainland by a land bridge.

A separate cargo airport
- Airport built to handle only cargo.
- The airport can be built on land or on water.
- No restrictions on night flights exist.
- All the cargo is intercontinental cargo.
- Only full freighters use the airport.
- No express cargo uses the airport.

REFERENCES

Amsterdam Airport Schiphol, *Jaarverslag 1994*, Schiphol, March 1995.

de Neufville, Richard, *Management of Mulit-Airport Systems: A Development Strategy*, Draft Paper for Discussion, November 13, 1995.

European-American Center for Policy Analysis, *Scenarios for Examining Infrastructure Options in the Netherlands*, DRU-1513-VW/VROM/EZ, January 1997a.

European-American Center for Policy Analysis, *Adaptive Policies, Policy Analysis, and Civil Aviation Policymaking*, DRU-1514-VW/VROM/EZ, January 1997b.

Miser, Hugh J. and Edward S. Quade (eds.), *Handbook of Systems Analysis: Overview of Uses, Procedures, Applications, and Practice*, John Wiley & Sons, Ltd., Chichester, England, 1985.

Project Mainport & Milieu Schiphol, *Planologische Kernbeslissing Schiphol en Omgeving, Deel 3: Nota van Toelichting*, Sdu Uitgeverij Plantijnstraat, 's-Gravenhage, February 1995.

Project Mainport & Milieu Schiphol, *Inventarisatie Economische Effecten, Eindrapport*, Ministerie van Verkeer en Waterstaat, 's-Gravenhage, December 1993.

Ministerie van Verkeer en Waterstaat, Directoraat Generaal Rijksluchtvaardienst, *Plan van Aanpak, Toeksomstige Nederlandse Luchtvaart Infrastructuur*, 's-Gravenhage, 7 July 1995.

SH&E Research, "A Review of the Infrastructure and Operations Developments at Northern European Airports," Briefing, July 1996.