The airport Network and Catchment area Competition Model: A comprehensive airport demand forecasting system using a partially observed database

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Abstract

In this paper we describe a comprehensive, pragmatic air demand model system that has been implemented for Amsterdam's Schiphol Airport. This model, called the Airport Network and Catchment area Competition Model (ACCM), provides forecasts of future air passenger volumes and aircraft movements not only based on generic passenger demand growth but also explicitly taking account of choices of air passengers among competing airports in Europe. The model uses a straightforward nested logit structure to represent choices of air passengers among departure airports, airport access modes, airlines, types of flight and main modes of transport. Because data is only available for Schiphol airport, synthetic data for other alternatives had to be generated. The forecasts are based on four scenarios that have been developed by the Dutch planning agencies (Global Economy, Strong Europe, Transatlantic Markets, Regional Communities). The total number of air passengers using Schiphol grows from 40 million in base year 2003 to 67 million in 2020 in the Regional Communities scenario, and up to 113 million in the Global Economy scenario. Aviation experts of the Dutch Ministry of Transport and other airport experts saw the forecasts that were obtained as credible.

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1. Introduction

Airport capacity planning requires long-term forecasts of aircraft movements. The classical approach to generate such forecasts has been the use of time series data together with econometric models to extrapolate observed patterns of growth into the future. More recently, the dramatically increased competition between airports, airlines and alliances on the one hand, and serious capacity problems on the other, has made this approach no longer adequate. Airport demand forecasts now need to focus heavily on the many competitive elements in addition to the growth element.

In this paper we describe a comprehensive, pragmatic air demand model system that has been implemented for Amsterdam's Schiphol Airport. This model, called the Airport Network and Catchment area Competition Model (ACCM), provides forecasts of future air passenger volumes and aircraft movements explicitly taking account of choices of air passengers among competing airports in Europe. The model uses a straightforward nested logit structure to represent choices of air passengers among alternative departure airports, transport modes to the airport, airlines/alliances/low cost carriers, types of flight (direct versus transfer), air routes, and main modes of transport (for those distances where car and high-speed train may be an alternative option).

Passenger forecasts for a target year are obtained by taking observed base year passenger numbers, and applying two factors to these:

- Firstly a growth factor, to express the global impact of key drivers of passenger demand growth such as population size, income, trade volume;
- Secondly a market share ratio factor, to express the increase (or decline) in attractiveness of the airport due to anticipated changes in its air network and landside-accessibility, relative to other (competing) airports.

The target year passenger forecasts are then converted into aircraft movements to assess whether or not the available runway capacity is adequate. Key inputs to the model are databases describing for base year and target year the level of service (travel times, costs) of the land-side accessibility of all departure airports considered, and the air-side networks of all departure and hub airports considered. The air-side networks (supply) are derived from a detailed OAG based flight simulation model developed elsewhere.

A particular characteristic of the ACCM implementation for Schiphol Airport is that it had to be developed using only a partial data set describing existing demand: although detailed OD information was available for air passengers using Schiphol Airport in 2003, no such data was available for other airports or other transport modes. In order to deal with this, a synthetic modelling approach was adopted, where the unobserved passenger segments for the base year were synthesised using modelled market share ratios between unobserved and observed segments for the base year together with the observed base year passenger volumes at Schipol airport. This process is elegant and appealing in principle, but is not without a number of problems when applied in a real case.

In the paper we will first set out the objectives of the ACCM as it was developed, and the operational and practical constraints that were imposed (section 2). In section 3, we will describe how the ACCM fits with model developments in the literature. Section 4 sketches the overall model structure, the modelled alternatives and the utility structures. Then we will – in section 5 - describe in some detail how we dealt with the partial data issue: the procedure to generate non-observed base year data, the validation, the problems encountered, and the solutions chosen. Section 6 shows a number of the results obtained while section 7 provide some conclusions and recommendations for further application of the methodology.

2. Objectives and scope of the ACCM

In 2004, the most recent passenger forecasts for Schiphol airport had been provided in 2001 in the ONL project (ONL stands for Development of National Airport). In the course of 2004 a study was carried out to see if these forecasts could still be used or if an update would be required. Two types of changes that occurred after 2001 were identified that could cause a need for new forecasts: short-term stagnations of growth and structural changes in the aviation sector. The war in Irak, 9/11 and SARS all led to short-term stagnations. Evidence from after the first Gulf War as well as after the more recent events suggests that such events are disruptive only on the short term but do not affect the structure of the aviation business. The occurrence of these stagnations alone would therefore not lead to a need for new forecasts, but would merely delay the expected growth somewhat. On the other hand, there were two structural changes to the aviation sector that did give rise to a need to prepare new forecasts for Schiphol airport: the rise of the low cost carriers and the alliance between KLM and Air France. Both developments affect the competition structures rather than the overall growth of the air transport market. It was decided that new forecasts needed to be developed. The next step was to see if the existing forecasting models were capable of taking into account the changing competition structures. The following conditions on the model instrument were formulated:

- The model needs to be easy to operate and transparent in its functions.
- The model needs to explicitly take into account competition between aviation and other transport modalities (e.g. train or car)
- The model needs to explicitly take into account competition between individual airlines and between alliances
- The model needs to be able to calculate welfare effects such as changes in consumer surplus.

The existing models could not fulfil all of these objectives, so it was decided to develop a new model instrument building on several existing models: ILCM (integrated airport competition model, see Kroes et. al., 1999 for a description), SCM (Schiphol competition model, see Ashley et. all, 1996 for a description) and AIRCO (airport competition model, see SEO 2004 for a description).

The new ACCM (Airport network and Catchment area Competition Model) was designed as a strategic model. It has to generate forecasts of number of passengers, amounts of freight and number of flights. It does not have to, for instance, simulate in detail a schedule of how these flights are distributed over the day or the exact (mix of) aircraft types that are used. For those sorts of applications more detailed operational models should be used.

In line with the strategic nature, the ACCM distinguishes 56 zones in total: 22 within the Netherlands, 5 in the rest of the catchment area (Belgium, Luxemburg, the Western parts of Germany, and Ile de France), 17 in the rest of Europe and 12 in the rest of the world. A total of 12 airports are considered as potential departure airport within the catchment area (see Figure 1), and 71 airports worldwide are classified as hub airports where people transfer.

Figure 1 Potential departure airports within the catchment area

3. Comprehensive Air Demand Models in the literature

A number of studies have addressed airport choice. Most of these studies use some form of the logit model to allocate passengers to airports. Ashford and Benchemam (1987), for instance, looked at airport choice in Central England. They used a MNL model for which they used flight frequency, travel time to the airport and airfare as the main explanatory variables in the utility function.

In recent years, several extensions to the MNL model have been made. Basar and Bhat (2004) separated choice set generation and airport choice in what they call a PCMNL (probabilistic choice set multinomial logit) model. They found that the statistical properties of the PCMNL specification were indeed better than those of the MNL specification, reflecting that passengers do not take into account all theoretically feasible airports when making a choice for a departure airport. Pels et. al. (2001) suggested that airport and airline choice are linked together and estimated both airport and airline choice in a NL (nested logit) model. Hess and Polak (2004) estimated a mixed MNL model for the combination of departure airport, airline and access mode choice. They tested for prevalence of random taste heterogeneity in a sample of air-travellers. Significant heterogeneity was identified for the in-vehicle access-time coefficient, the flight frequency coefficient, and the access cost coefficient. Hess and Polak concluded that while allowing for such variation leads only to marginal (yet significant) gains in model fit, it avoids the bias in trade-off resulting from the use of fixed coefficients in the MNL model. It also leads to important insights into the differences in choice behaviour across individuals.

To our knowledge, none of the models mentioned above are used in practical forecasting and/or in the applied policy process. The CAA (UK) is one of the rare parties using a practical forecasting system in which competition effects are modelled (CAA, 1998). It uses a Passenger Allocation Model, known as SPAM, which main purpose it is to distribute passenger forecasts for the total UK between 27 individual UK airports. The central part of SPAM models passengers who start/finish their journeys in the UK and fly to/from an international destination. For each origin/destination zone and foreign airport/group of airports pair, passengers choose between flying directly from any modelled UK airport offering a service and in the scheduled case from a pre-specified list of interline routings that are either currently used or geographically plausible. This choice is made by assigning costs to each option and allocating the passengers using a standard MNL equation. Four different passenger types are distinguished, based on nationality and journey purpose: UK business, UK leisure, foreign business and foreign leisure. Variables in the SPAM utility function are – among others - access cost, flight time, and frequency. Ticket prices are excluded. The SPAM approach is similar to the approach taken in the development of the ACCM.

4. Structure of the ACCM

The Airport Catchment area Competition Model (ACCM) currently calculates demand development of passengers, freight and movements without looking at possible capacity constraints.[2] The model consists of four modules:

- The Airside Level of Service (LOS) Module
- The Passenger Module
- The Freight Module
- The Movements Module

The following figure shows the relationship between these modules.

[2] A new, recently awarded, project aims to build in the effects of capacity constraints and policy measures.

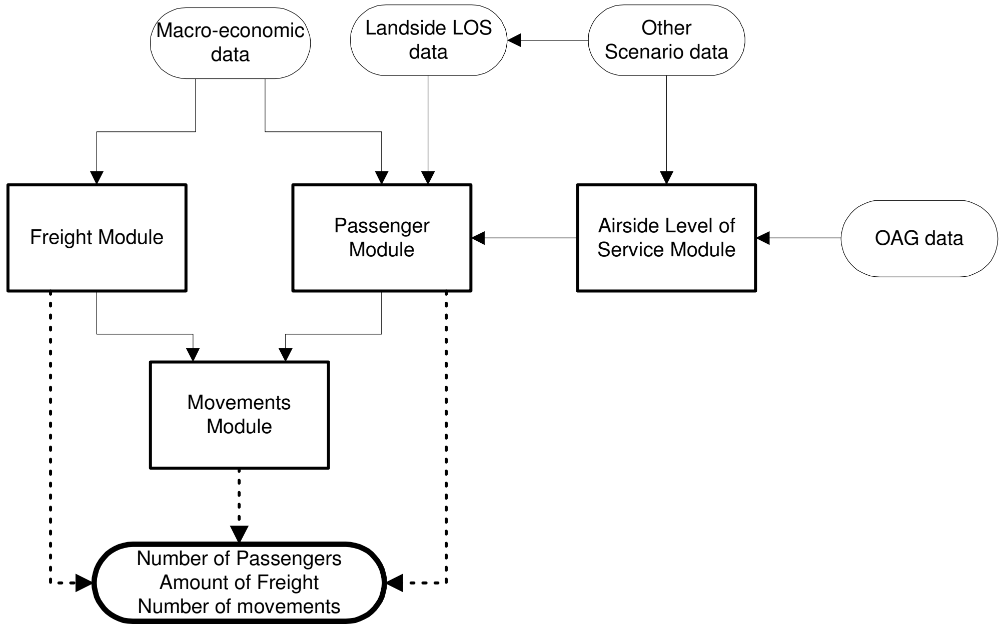


Figure 2 Overview modules ACCM model

- The **Airside Level Of Service (LOS)** module determines flight frequencies, travel times and a proxy for ticket prices for all combinations of origin and destination zones.
- The **Passenger module** calculates the number of passengers that makes use of Schiphol. This module uses macro-economic scenario data, landside level-of-service data and the output of the Airside LOS module.
- The **Freight module** calculates the amount of freight (in tonnes) that is transported from and to Schiphol. It uses macro-economic scenario data, such as GDP growth figures and a multiplier.
- In the **Movements module** the number of movements is calculated based on the number of passengers and the amount of freight. For all connections, the average aircraft size is determined based on the number of passengers and route characteristics such as the share of business travellers, travel time and competition on a route.

The Airside Level of Service module is a stand-alone Microsoft Excel application that was developed by AAE/SEO[3]. The passenger module, freight module, and movements module have all been implemented as a Delphi application for use on

[3] See AAE/SEO, RAND Europe (2005) for a description

a standard PC. Districon developed the freight module[4]. The remainder of this section will discuss the passenger module in detail.

Passenger Module

The Passenger Module provides forecasts of the number of passengers that uses Schiphol Airport in 2020. This calculation is based on a shift of market shares of Schiphol in 2020 compared to the market share in 2003, and on growth of passenger travel due to economic growth. Market shares are computed at the OD pair level (zone to zone). Schematically, the model works as depicted in Figure 3.

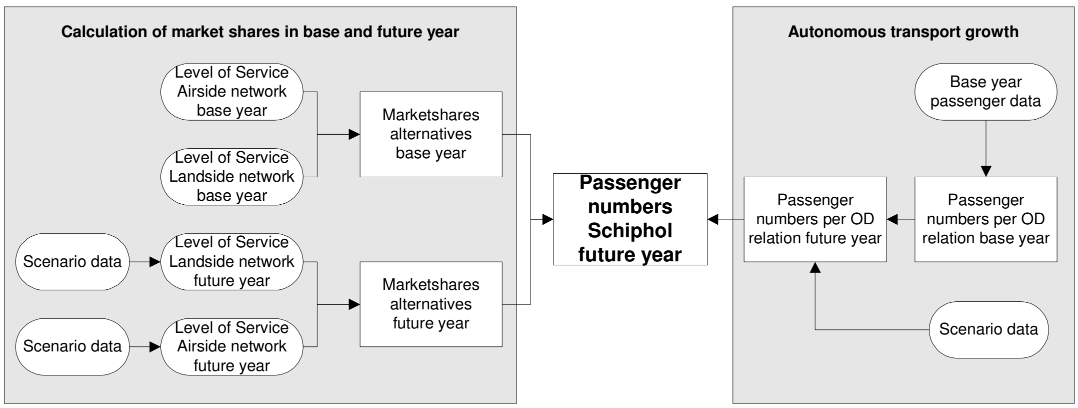


Figure 3 passenger module

The market shares are calculated for both the base year and the future year. Differences in these market shares stem from differences in the airside and landside level of service networks. Changes in these networks are based on developments between base year and future year and are defined for four scenarios (see section 6). The passenger numbers per OD relation in the future year is based on the passenger numbers per OD relation in the base year combined with a growth factor, which is based on scenario data. The passenger numbers per OD relation in the base year are synthetic data created from data on passenger numbers of Schiphol airport in the base year (see section 5 for a description of how this synthetic data is created). Both the calculation of market shares and the transport growth will be discussed separately.

[4] See AAE/SEO, RAND Europe (2005) for a description

Calculation of market shares

Market shares are calculated for both the base year (2003) and a future year (2020) for both business and non-business travellers for all alternatives. The calculation of market shares is based on a nested logit model. Three nests are distinguished: main mode choice, route choice (which includes departure airport, hub airport[5] and alliance choice), and access mode choice. The following figure gives an overview of this structure.

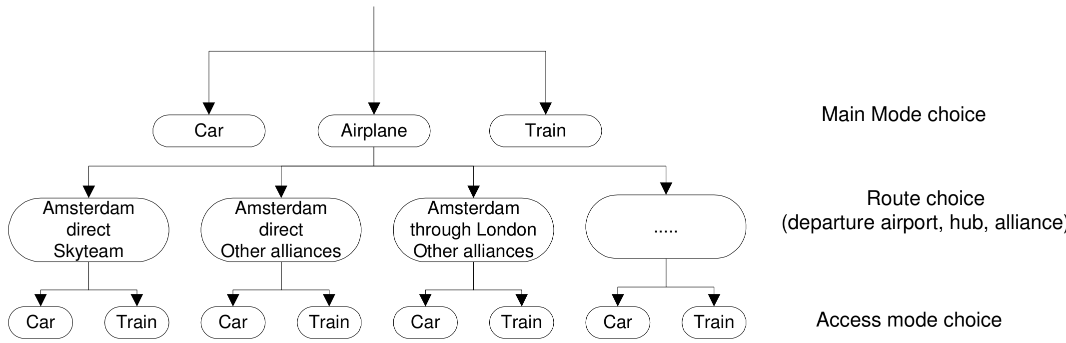


Figure 4 Structure of the nested choice model

First, a choice needs to be made between the main modes options car, train and airplane. If airplane is the mode of preference, a route needs to be chosen as well. The routes are characterised by departure airport, indirect or direct flight (whereby there are a maximum of 71 hubs a person can choose from), and an airline alliance (either Skyteam, other full service carriers/alliances, or a low cost carrier). After choosing a route an access mode (car or train) has to be decided on.

We discussed before that there are 56 zones scattered across the world. Not all choices have to be made possible for all zone combinations. For instance, for origins in the rest of the world and destination in the rest of the world, main modes other than airplane are not possible. As these zones do not include the catchment area airports, no choice for an access mode has to be made. The following table shows the different choice set structures for different OD combinations.

[5] In the case of a direct flight, no hub airport is chosen.

Table 1 Alternatives for origin-destination combinations

		Destination		
		Catchment Area	Rest of Europe	Rest of World
Origin	Catchment Area	This type of traffic is only included when departing/ arriving at FRA or CDG	Main mode choice Route choice Access mode choice	Route choice Access mode choice
	Rest of Europe	Main mode choice Route choice	Route choice	Route choice
	Rest of World	Route choice	Route choice	Route choice

For all three choices (main mode choice, route choice, access mode choice) separate utility functions for both business and non-business travellers are defined.

$$U_{Access}(i) = \beta_{Access} \cdot GC_{Access}(i)$$

$$U_{Route}(j) = \begin{cases} \alpha_{route} \cdot Ln(Freq(j)) + \beta_{route} \cdot GC_{route}(j) + \gamma_{route} \cdot Logsum_{access} & \text{if route starts in catchment area} \\ \alpha_{\mathrm{route}} \cdot Ln(Freq(j)) + \beta_{route} \cdot GC_{route}(j) & \text{else} \end{cases}$$

$$U_{Main\,\mathrm{mod}\,e}(k) = \begin{cases} \gamma_{main\,\mathrm{mod}\,e} \cdot Logsum_{route} & \text{if } k = airplane \\ \beta_{main\,\mathrm{mod}\,e} \cdot GC_{main\,\mathrm{mod}\,e}(k) + \delta_{Main\,\mathrm{mod}\,e} & \text{else} \end{cases}$$

Where:

U(i)	Utility of alternative i
GC(i)	Generalised Costs of alternative i
Freq(j)	Frequency of alternative j
Logsum	Accessibility measure
α, β, γ	Coefficients

There are two modes to choose from in the **access mode choice** process: car and train. The utility function for the access mode choice consists out of a generalised cost function and coefficient to translate these generalised costs into utility. The value of this coefficient is described at the end of this section.

The generalised cost functions are defined for single trips for both modes and are based on a cost and a time component.

$$GC_{Access}(i) = \begin{cases} \dfrac{(FC \cdot FU \cdot TD) + PC}{LF} + TTC \cdot VoT & if\ i = auto \\ TPT + (AT + VT + ET) \cdot VoT & if\ i = train \end{cases}$$

Where

FC	Fuelcost	€/liter
FU	Fuelusage	km/liter
TD	Tripdistance	km
PC	Parking cost	€
LF	Load factor	Average number of persons per car
TTC	Triptime car	Car travel time (minutes)
VoT	Value of Time	€/hour
TPT	Ticketprice train	Train ticket (€)
AT	Accesstime	Travel time from origin to train station (minutes)
VT	In-vehicle time	Train travel time (minutes)
ET	Egress time	Travel time from train station to airport/destination (minutes)

The utility for ***route choice*** consists out of three components:

- A flight frequency term
- A generalised cost function
- An accessibility measure

Each of these components is translated into utility through a coefficient, which value will be discussed at the end of this section. The flight frequency term is expressed as the natural logarithm of the flight frequency. It is included to ensure that market shares are – in the first order - proportional to the frequency flown. The generalised cost function is defined for single trips and is based on travel time, interval time and travel cost. The accessibility measure represents the landside accessibility of the departure airport and is defined as the logsum over all access mode alternatives.

$$GC_{Route}(j) = TPA + (TTA + CIT + COT) \cdot VoT + 0.5 \cdot (\frac{112}{Freq}) \cdot VoIT$$

$$Logsum_{Access} = \log(\sum_i e^{U_{Access}(i)})$$

Where

TPA	Ticketprice air	€
TTA	Traveltime air	minutes
CIT	Check-in time	minutes
COT	Check-out time	minutes
VoT	Value of Time	€ per hour
Freq	Frequency	Number of flights per day
VoIT	Value of Interval Time	€ per hour

The utility of the ***main mode alternatives*** train and car is characterised by a generalised cost function, again translated into utility through a coefficient. The generalised cost functions are defined for single trips for both modes and are based on a cost and a time component. The utility of the alternative airplane is represented through an accessibility measure which indicates how accessible a certain destination is by air. This term is a logsum over all possible air route alternatives.

$$GC_{Main\ mode}(k) = \begin{cases} \dfrac{(FC \cdot FU \cdot TD) + PC}{LF} + TTC \cdot VoT & \text{k = auto} \\ TPT + (AT + VT + ET) \cdot VoT & \text{k = train} \\ Logsum_{route} & \text{k = airplane} \end{cases}$$

$$Logsum_{Route} = \log\left(\sum_j e^{U_{Route}(j)}\right)$$

Where:

FC	Fuelcost	€/liter
FU	Fuelusage	Km/liter
TD	Tripdistance	Km
PC	Parking cost	€
LF	LoadFactor	Average number of persons per car
TTC	Triptime	Car travel time (minutes)
VoT	Value of Time	€ per hour
TPT	Ticketprice	Train ticket (€)
AT	Accesstime	Travel time from origin to train station (minutes)
VT	In-vehicle time	Train travel time (minutes)
ET	Egresstime	Travel time from train station to airport/destination (minutes)

All the components of the three levels of logit functions are translated into utility through coefficients. Within the ACCM, we made use of existing coefficients that were used in comparable models such as the SCM and ILCM (see Table 2).

Table 2 Coefficients used in ACCM for the base year

Coefficient		Choice level	Mode	Business	Non-business
α	Frequency coefficient	Route		1	1
β	Scale coefficient	Access		-0.012	-0.03
		Route		-0.012	-0.03
		Main mode		-0.006	-0.015
γ	Logsum coefficient	Route		1	1
		Main mode		0.5	0.5
δ	Mode specific constant	Main mode	Car	1.75	
		Main mode	Train	-0.75	

Based on the utilities of each of the alternatives, the market shares for Schiphol airport are calculated. Market shares are defined as the probability that a certain alternative is chosen. The market share of alternative *i* is defined as:

$$P_i = \frac{e^{U_i}}{\sum_j e^{U_j}}$$

Where *j* runs over all possible alternatives.

Economic growth

Apart from a shift in the market share of Schiphol, autonomous growth of passenger transport as a result of economic growth is to be expected. This growth is calculated on a zone-to-zone level and is determined either on the route or (if applicable) on the main mode level. In the latter case, the share that travels by airplane follows from the calculation of the market shares.

The growth factor is different for business and non-business travellers. The autonomous growth in business travellers between zone A and zone B depends on the development of international trade and the price levels of trips between zone A and B. The autonomous growth in non-business travellers depends on the development of GDP per capita of the origin zone, price levels and population growth which are then translated into passenger growth using income, price and trade elasticities.

5. Using a Partial OD Database

The model structure described above is applied at a zone-to-zone level: for each OD pair (and each purpose) the model computes the change of market shares for all alternatives, and the growth of the total number of passengers. By combining this with the observed passengers numbers for each of the alternatives in a base year, the total number of passengers for each of the alternatives in a future year can be calculated.

The description of this method suggests that data on passenger numbers needs to be available for all OD-pairs for all travel alternatives in the base year. Unfortunately, such data is not available. Accurate data is only available for Schiphol airport through a survey held among departing passengers. Data on passenger numbers for aviation alternatives that do not pass through Schiphol and data on passenger number for non-aviation alternatives are not available.

The model deals with this by mirroring the process: the model is run to calculate the market shares in the base year. From the calculated market share for Schiphol and the observed numbers of passengers at Schiphol, the total number of passengers between each origin and each destination area (a so-called OD-relation, for example between area Groningen and area Spain) in the base year is calculated.

In general, the unobserved volume for an alternative *i* is calculated through multiplying the observed volume of alternative *j* with the ratio between the market share of alternative *i* and j.

$$Vol_{unobs}(i) = \frac{MS(i)}{MS(j)} \cdot Vol_{obs}(j)$$

where

$Vol_{unobs}(i)$	Unobserved passenger volume of alternative i
$Vol_{obs}(j)$	Observed passenger volume of alternative j
MS(i)	Market share of alternative i
MS(j)	Market share of alternative j

This method makes it possible to generate synthetic data and therefore to model passenger numbers at other airports than Schiphol airport. This in turn, yields the possibility to calculate competition effects accurately. However, the application of this method raises some practical issues:

- If the calculated market share of Schiphol airport for a certain OD-relation is zero ($MS(j) = 0$), the total number of passengers for this origin and destination combination cannot be calculated. In our model such OD-relations were excluded from further analysis. This is no problem, since these are usually origins and destinations which are near each other, but which are far from Schiphol airport so it is unlikely that these OD combinations are important for other airports in the catchment area (e.g. passengers travelling from US Southeast to US Southwest are unlikely to travel through Schiphol).
- If the calculated market share of Schiphol airport for a certain OD-relation is small ($MS(j) \approx 0$), the total number of passengers for this origin and destination combination becomes highly uncertain and might become unrealistically large. To prevent such overestimation a minimum market share of 1% for Schiphol is set, all other market shares are corrected accordingly. This needed to be done for only 2% of all OD-combinations.

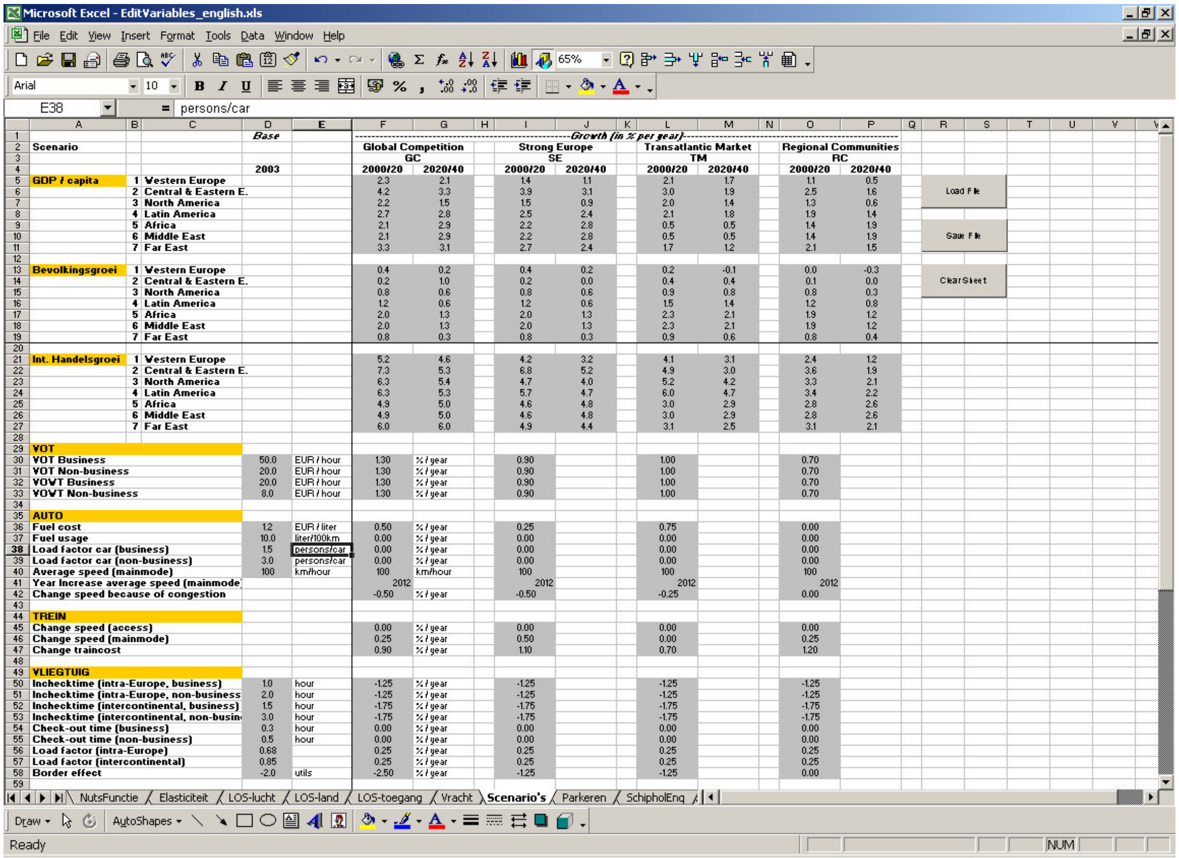
Furthermore, there were a few exceptional cases where the calculated market share of Schiphol airport was zero, but where still a number of passengers was observed in the survey, or vice versa (Schiphol market share was positive, but no passengers were observed). These OD-relations were also excluded from further analysis.

Due to these exclusions of a number of OD-relations the modelled number of passengers from Schiphol airport to each world region was slightly different from the observed number in the survey. We applied scaling factors to correct for this. These correction factors were typically 1%.

6. Implementation and Results

The forecasts are based on four scenarios that have been developed by the Dutch planning agencies (Global Economy, Strong Europe, Transatlantic Markets, Regional Communities). The definitive publication of the scenarios by the planning agencies still had to appear when writing this article. In total there are four scenarios, each of which is based on one of the general scenarios for Europe and the Netherlands (CPB, 2004a and 2004b). The critical uncertainties in the scenarios are the level of European coordination and the influence of national institutions. On the basis of material available to the project team in March 2005, a qualitative sketch of the implications of various developments for the aviation sector is given. These have been quantified for the forecast year (2020).

In the passenger module scenario specific assumptions were made on fuel cost, travel time and the level of congestion in the access to the airport. Scenario specific assumptions were also made on the structure of the airside and landside networks in 2020. In order to facilitate usage, the input data can be easily adapted in Microsoft Excel, after which a visual basic procedure transfers the data into the format needed for the Delphi application. Figure 5 gives an overview of the main scenario data.



		Base		Global Competition GC		Strong Europe SE		Transatlantic Market TM		Regional Communities RC	
Scenario		2003		2000/20	2020/40	2000/20	2020/40	2000/20	2020/40	2000/20	2020/40
GDP / capita	1 Western Europe			2.3	2.1	1.4	1.1	2.1	1.7	1.1	0.5
	2 Central & Eastern E.			4.2	3.3	3.9	3.1	3.0	1.9	2.5	1.6
	3 North America			2.2	1.5	1.5	0.9	2.0	1.4	1.3	0.6
	4 Latin America			2.7	2.8	2.5	2.4	2.1	1.8	1.9	1.4
	5 Africa			2.1	2.9	2.2	2.8	0.5	0.5	1.4	1.9
	6 Middle East			2.1	2.9	2.2	2.8	0.5	0.5	1.4	1.9
	7 Far East			3.3	3.1	2.7	2.4	1.7	1.2	2.1	1.5
Bevolkingsgroei	1 Western Europe			0.4	0.2	0.4	0.2	0.2	-0.1	0.0	-0.3
	2 Central & Eastern E.			0.2	1.0	0.2	0.0	0.4	0.4	0.1	0.0
	3 North America			0.8	0.6	0.8	0.6	0.9	0.8	0.8	0.3
	4 Latin America			1.2	0.6	1.2	0.6	1.5	1.4	1.2	0.8
	5 Africa			2.0	1.3	2.0	1.3	2.3	2.1	1.9	1.2
	6 Middle East			2.0	1.3	2.0	1.3	2.3	2.1	1.9	1.2
	7 Far East			0.8	0.3	0.8	0.3	0.9	0.6	0.8	0.4
Int. Handelsgroei	1 Western Europe			5.2	4.6	4.2	3.2	4.1	3.1	2.4	1.2
	2 Central & Eastern E.			7.3	5.3	6.8	5.2	4.9	3.0	3.6	1.9
	3 North America			6.3	5.4	4.7	4.0	5.2	4.2	3.3	2.1
	4 Latin America			6.3	5.3	5.7	4.7	6.0	4.7	3.4	2.2
	5 Africa			4.9	5.0	4.6	4.8	3.0	2.9	2.8	2.6
	6 Middle East			4.9	5.0	4.6	4.8	3.0	2.9	2.8	2.6
	7 Far East			6.0	6.0	4.9	4.4	3.1	2.5	3.1	2.1
VOT											
VOT Business		50.0	EUR / hour	1.30	% / year	0.90		1.00		0.70	
VOT Non-business		20.0	EUR / hour	1.30	% / year	0.90		1.00		0.70	
VOWT Business		20.0	EUR / hour	1.30	% / year	0.90		1.00		0.70	
VOWT Non-business		8.0	EUR / hour	1.30	% / year	0.90		1.00		0.70	
AUTO											
Fuel cost		1.2	EUR / liter	0.50	% / year	0.25		0.75		0.00	
Fuel usage		10.0	liter/100km	0.00	% / year	0.00		0.00		0.00	
Load factor car (business)		1.5	persons/car	0.00	% / year	0.00		0.00		0.00	
Load factor car (non-business)		3.0	persons/car	0.00	% / year	0.00		0.00		0.00	
Average speed (mainmode)		100	km/hour	100	km/hour	100		100		100	
Year Increase average speed (mainmode)				2012		2012		2012		2012	
Change speed because of congestion				-0.50	% / year	-0.50		-0.25		0.00	
TREIN											
Change speed (access)				0.00	% / year	0.00		0.00		0.00	
Change speed (mainmode)				0.25	% / year	0.50		0.00		0.25	
Change traincost				0.90	% / year	1.10		0.70		1.20	
VLIEGTUIG											
Inchecktime (intra-Europe, business)		1.0	hour	-1.25	% / year	-1.25		-1.25		-1.25	
Inchecktime (intra-Europe, non-business		2.0	hour	-1.25	% / year	-1.25		-1.25		-1.25	
Inchecktime (intercontinental, business)		1.5	hour	-1.75	% / year	-1.75		-1.75		-1.75	
Inchecktime (intercontinental, non-busin		3.0	hour	-1.75	% / year	-1.75		-1.75		-1.75	
Check-out time (business)		0.3	hour	0.00	% / year	0.00		0.00		0.00	
Check-out time (non-business)		0.5	hour	0.00	% / year	0.00		0.00		0.00	
Load factor (intra-Europe)		0.68		0.25	% / year	0.25		0.25		0.25	
Load factor (intercontinental)		0.85		0.25	% / year	0.25		0.25		0.25	
Border effect		-2.0	utils	-2.50	% / year	-1.25		-1.25		0.00	

Figure 5 Example of scenario input data

The forecast results are presented below for all four scenarios. The results are preliminary and may be subjected to change when the WLO scenarios are finalised.

The total number of air passengers using Schiphol grows from 40 million in base year 2003 to 67 million in 2020 in the RC scenario, and up to 113 million in the GE scenario. There are hardly any shifts in the distribution of business and non-business travellers. In 2003, around 59% of passengers consisted out of OD passengers (passengers that use Schiphol as their first or last airport in their journey). In all scenarios, this percentage increases substantially, to 67% in SE and even 74% in GE. This leads to a decrease in the percentage of transfer travellers, which can partly be explained by the rise of the low cost carriers, whose share of passenger volume increases from 16 to 21%. Because transfer traffic is particularly vulnerable for these low cost carriers, the Skyteam alliance share of passenger volume decreases more than the decrease of other airline alliances. The rise of the low cost carriers causes an extra pressure on prices causing a substantial growth of intra-European traffic in all scenarios. This growth is significantly higher than growth on intercontinental routes. In 2003, nearly three-quarters (72.8%) of the Schiphol air passengers had an origin or destination in the Randstad. This percentage remains relatively constant in all scenarios (between 73.8% and 74.6%). In 2003, 3.2% of departing passengers originates in Belgium, Luxemburg, the Western part of Germany or Ile de France. In 2020, this percentage varies between 2.3% (RC scenario) and 3.7% (GE scenario). Table 3 gives an overview of the main results.

Table 3 Summary of ACCM results –passengers (millions)

	Base year	**Global Economy**		**Strong Europe**		**Transatlantic Market**		**Regional Communities**	
	Number	Number	Growth	Number	Growth	Number	Growth	Number	Growth
Total	39.9	113.1	6.3%	76.2	3.9%	97.0	5.4%	68.8	3.3%
Business	15.2	42.0	6.2%	30.4	4.2%	35.0	5.0%	24.9	2.9%
Non-business	24.6	71.1	6.4%	45.7	3.7%	62.0	5.6%	43.9	3.5%
OD traffic	23.5	83.7	7.8%	51.2	4.7%	70.2	6.7%	48.0	4.3%
- EUR	17.2	66.2	8.2%	38.6	4.9%	55.7	7.2%	36.6	4.5%
- ICA	6.2	17.5	6.2%	12.6	4.2%	14.5	5.1%	11.5	3.6%
Transfer	16.4	29.4	3.5%	25.0	2.5%	26.8	2.9%	20.7	1.4%
- EUR-EUR	3.9	7.1	3.7%	5.5	2.1%	6.4	3.0%	4.6	1.0%
- EUR-ICA	10.3	18.0	3.3%	15.5	2.4%	16.6	2.8%	12.9	1.3%
- ICA-ICA	2.2	4.3	3.9%	4.1	3.6%	3.8	3.2%	3.3	2.3%
Skyteam	26.9	67.3	5.5%	47.1	3.3%	58.8	4.7%	42.2	1.0%
Other alliances	6.4	21.7	7.4%	12.5	4.0%	17.4	6.1%	11.8	1.3%
Low cost carriers	6.5	24.2	8.0%	16.6	5.6%	20.7	7.0%	14.8	2.3%

EUR= Europe; ICA = intercontinental

7. Conclusions and recommendations

In this paper we have described a comprehensive, practical air demand model system that has been implemented for Amsterdam's Schiphol Airport, the Airport Network and Catchment area Competition Model (ACCM). We have chosen a pragmatic approach, hence, coefficient have been "borrowed" from research elsewhere rather than calibrated on local data and the model is not state-of-the-art.

On the other hand this approach has been able to produce very reasonable results, even though a complete database for the base year 2003 was not available. The partial database approach seems to work well, at least for travel alternatives that are "close" to Schiphol airport, and where Schiphol has a substantial market share. The passenger numbers and aircraft movements forecasts that were obtained were seen as credible by aviation experts of the Dutch Ministry of Transport and other airport experts. Another perceived benefit of the model is its transparency: policy makers were able to understand the basic principles, which helped in gaining faith in and support for its outcomes.

The model system also has its limitations, not only in terms of the type of specification and the lack of calibrated coefficients, but also in terms of the actors and behavioural mechanisms that are represented inside the system:

- A first and obvious limitation is the fact that currently no airport capacities are taken into account. So the results reported above are unconstrained forecasts, assuming no limits apply to runway capacity and environmental indicators. A new version of the model that does incorporate such constraints is currently under development.
- A second limitation is that supply, the air level of service, is taken as exogenous and no feedback takes place between demand (passenger numbers) and supply (numbers of flights). Therefore the outcomes may not be internally consistent. The new version of the model will explicitly model how airlines increase or reduce their frequencies as a function of variations in demand.
- A third limitation is that the freight model in ACCM is currently rather simple, and does not explicitly model competition between Schiphol and other airports for air freight. It would be desirable to improve on this, and also to increase the geographical detail of the freight model database.

We recommend carrying out further tests to assess the quality of the model, both its ability to represent the current situation and its ability to forecast change. For that we would require an accurate and much broader database than was available now, ideally also including time series information. Finally we have the desire to apply this concept to another geographic region, with different airports in the catchment area, possibly at a nation-wide level, and hopefully with good quality data available. Ideally that would include the possibility to calibrate the model structures locally, so that optimised local coefficients could be obtained.

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