WELFARE EFFECTS OF CAPACITY CONSTRAINTS AT SCHIPHOL AIRPORT – A NEW MODEL TO FORECAST AIR DEMAND

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1. INTRODUCTION

Dutch government policy allows the continuing growth of air traffic within strict safety and environmental limits. In order to assess the impacts of new policies on the development of Schiphol airport, the Ministry of Transport, Public Works and Water Management required a new model to forecast demand for air travel under a wide range of scenarios.

Historically air traffic forecasts have been made by extrapolating observed patterns of growth. The extrapolation of growth patterns was mainly driven by expected future macro-economic trends. The implicit assumption was that the market share of Schiphol would remain constant, even in the longer term. Such an assumption may be justified in a largely regulated environment. However, in recent years new dynamics and constraints have entered the system. Liberalisation has led to more competition between airlines and airports. This dramatically increased competition between airports, airlines and alliances on the one hand, and serious airport capacity issues on the other, has made extrapolations of historic demand no longer adequate.

Airport demand forecasts now need to focus heavily on the many competitive elements and on the physical and environmental constraints in addition to standard growth scenarios.

In order to provide the required new forecasting capability for Schiphol airport, we have developed a new model for the Ministry of Transport, Public Works and Water Management. This model was required to have the following characteristics:

- strategic nature
- quick and pragmatic application
- transparent methodology
- allow for assessment of multiple scenarios
- take into account the competition between airports and airlines, (including low cost airlines and alliances) in North-West Europe
- take into account the landside accessibility of the airports under consideration
- take into account the effects of both airport capacity and noise constraints
- assess the implications of policy measures (such as levies for specific market segments)
- assess the welfare effects of the capacity constraints and policy measures and of a wide range of possible policies.

Before developing a new forecasting methodology, an assessment was made of the extent to which the existing models would be useful in the light of these (partially new) requirements. From this assessment it was concluded that several tools were available to address these new issues. However, each of these models addressed only specific issues with a limited scope, as they had been developed earlier to answer only these specific issues. Simply combining all these available tools would lead to inconsistencies in the methodology. Moreover these tools were in some cases insufficiently transparent and/or used outdated statistics.

It was concluded that a new tool was needed, that would integrate functionalities addressing these issues, in a consistent and transparent way. Nevertheless, as far as possible and relevant, model mechanisms from the already existing tools should be taken on board in the new model. This, ultimately, has led to the development of the ACCM model (Airport Catchment area Competition Model).

In this paper we provide a brief description of this new ACCM model and its main components. Then we report an application of the model to assess capacity issues and a range of policy measures for the planning horizons 2020 and 2040. We conclude by discussing how the model concept can be used to assist in capacity planning for airports other than Schiphol airport.

2. MODEL STRUCTURE

The model considers world wide traffic flows to, from and through the airports under consideration. The architecture of the simulation system consists of two modules: a module to forecast traveller choices and a module to forecast airline choices. The traveller choice-module requires current passenger counts and level-of-services for calculating travellers' preferences for the available alternatives in the base year (i.e. 2003). The airline choice module converts the passenger numbers into number of yearly flights per type of aircraft and per period of the day (see Figure 1).

The number of passengers in the base year is extrapolated towards the forecast year (i.e. 2020) using a growth factor that depends on economic and price developments. The distribution over the available alternatives in the forecast year is calculated again in the travellers' choice module using a level-of-service for the forecast year. This module is connected to the airline choice module by an iterative loop to meet capacity constraints.

2.1 Traveller Choice Module

The traveller choice module simulates the number of (one-way) trips that travellers make between an origin and a destination zone. Furthermore, it calculates the distribution of these trips over the available alternatives. The zones are relatively small within the catchment area of Schiphol airport

(Netherlands, Belgium, northern part of France, western part of Germany), more aggregated in the rest of Europe and very large in the rest of the World.

For trips with an origin (or destination) in the catchment area of Schiphol, the model forecasts the market shares for each of the possible departure (or arrival) airports in this region (Figure 2) and the market shares of the mode used to access (or egress from) the airport. For trips with an origin (or destination) in the catchment area of Schiphol and with a destination (or origin) somewhere in the rest of Europe the model forecasts the distribution over the available main modes as well (car, train, aircraft). This specific structure reflects air passengers choices among competing departure and hub airports in North-west Europe.

The number of passengers travelling by air between an origin and a destination are taken from observed numbers at Schiphol airport, see Kroes et *al.* (2005) for more details on how a complete OD-matrix was derived from a partially observed database.

The market shares of the available travel alternatives are determined by simulating traveller choices at one to three levels (Figure 3): choice between main modes (car, train, or aircraft), choice between available routes (specified by departure airport, airline, direct flight or indirect via a hub), and choice between access modes to the airport (car or train). Not all choices are modelled for each origin-destination combination, see Table 1.

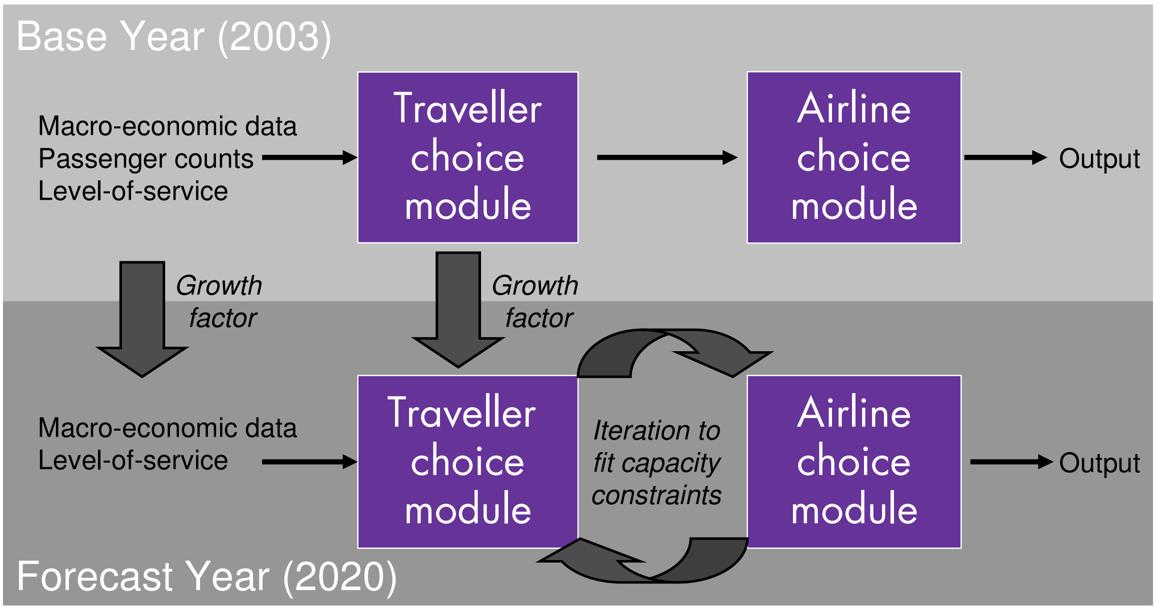

Figure 1: Basic structure of the ACCM model

Figure 2: Assumed catchment area of Amsterdam Schiphol airport

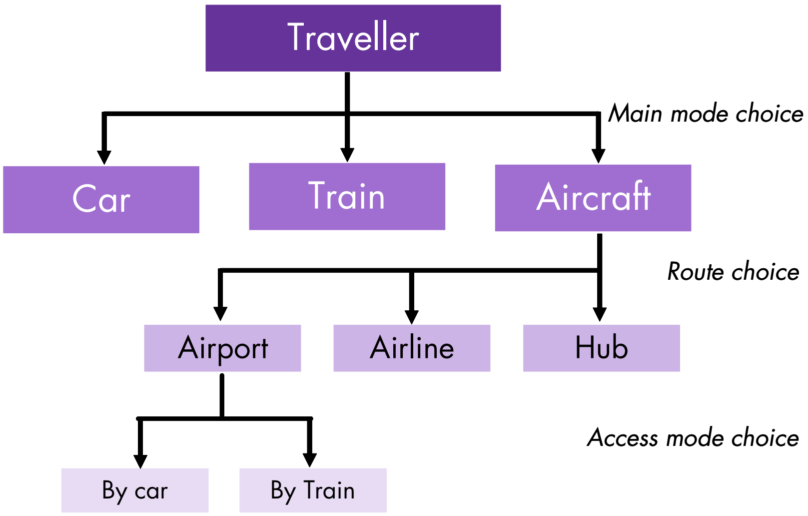

Figure 3: Structure of traveller choices module

Table 1: Choices that are modelled for each origin-destination combination

		Destination		
		Catchment area	***Rest of Europe***	***Rest of World***
Origin	***Catchment area***	*(out of scope)*	main mode choice route choice access mode choice	route choice access mode choice
	Rest of Europe	main mode choice route choice egress mode choice	route choice	route choice
	Rest of World	route choice egress mode choice	route choice	route choice

We use random utility models of the logit type to define traveller choices. Travel and transfer times, travel costs and service frequencies are the main determinants for the utility functions.

Access mode choice

There are two alternatives: car and train. Generalised costs for the car mode are determined by fuel cost, parking cost and travel time. Travel times are converted into generalised cost by means of multiplication by an assumed value-of-time depending on the travel purpose (business or non-business). Generalised costs for the train mode are determined by the train fare and generalised train travel time. Travel fares and times are taken from an input file with level-of-service information.

The same model is used to model the egress mode in case the destination of the trip is in the catchment area.

Route choice

Alternatives are defined by airline (Skyteam, Star Alliance, OneWorld, low-cost airlines, other airlines), by hub (direct flight, or one of the 64 international hubs considered), and by access/egress airport (only if origin or destination is in the catchment area). The utility of each alternative is determined by the logarithm of the number of flights per week, by a generalised cost term (determined by an assumed ticket fare and flight time (with an extra penalty for an indirect flight)) and by an accessibility term for the airport (only in catchment area). This accessibility term is the logsum of the access mode choice model.

Main mode choice

There are three alternatives: car, train and aircraft. The utilities for the first two modes are determined by travel cost (fuel or train fare) and generalised travel time; the utility of the air alternative is determined by the logsum of the route choice model.

Freight model

In addition, both the volume of air freight and its distribution among alternative airlines and full freighters and belly-freight are simulated.

2.2 Airline Choice Module

Under most scenarios a substantial growth of air traffic towards 2020 is predicted. The resulting numbers of aircraft movements often exceed the current runway capacity. Furthermore, the amount of noise generated by aircraft exceeds existing legal boundaries. To take these effects into account, an airline choice module was developed that simulates the deployment of aircraft to transport the passenger volume as predicted by the traveller module. This module has three dimensions: size of the aircraft (nine classes), technological status of the aircraft (five classes) and time of departure/arrival (four periods per day), resulting in 180 possible combinations.

We have used observed distributions and foreseeable trends to predict the future distribution over these 180 combinations. From this data the implicit preferences utility values for each of these combinations are inferred. When for instance airport charges are introduced, these utilities are modified (costs per seat are added to the utility using an assumed cost coefficient) and new distributions over the 180 combinations are calculated (Figure 4).

An estimate of the total number of movements (per year and per period of the day) and the total environmental burden (i.e. the amount of noise generated by the departing and arriving aircraft) can be calculated using the airline choice model.

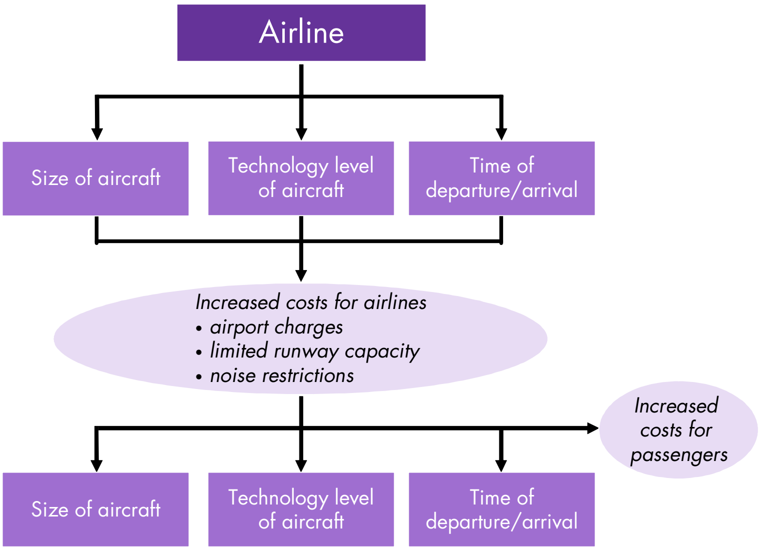

Figure 4: Structure of the airline choices module

2.3 Growth Factors

For the base year the passenger choice and the airline choice module are run once to calculate a base scenario. The output values for the number of passengers, the number of flights, and the amount of noise produced are calibrated using correction factors to match the observed values in 2003. Typically only small corrections are necessary.

For the forecast year (2020 or 2040) we specify:

- the expected change in air level-of-service (increase of frequencies, change in air fares)
- the expected change in level-of-service of the land modes (fuel cost, train fares)
- the expected change in value-of-time (due to real increase of incomes)
- the expected change in the airlines' preferences for the deployment of aircrafts of certain sizes (due to the availability of larger aircraft)
- the expected change in the airlines' preferences for the deployment of aircrafts of certain technology (due to the availability of newer (and more quite) aircraft). For this we use a simple fleet aging and replacement model.

The number of travellers in the forecast year travelling between an origin and a destination zone are determined by applying a growth factor to the number of travellers in the base year. For non-business travellers this growth factor depends on population growth in the origin zone, real GDP per capita growth in the origin zone and the price growth in both origin and destination zones. For business travellers this growth factor depends on trade growth between the origin and destination zone and price growth. Price elasticities are within the ranges indicated by Brons et al. (2002).

The passenger choice module is then run again to determine the market shares of the available alternatives in the forecast year. Consecutively, the airline choice module is run again to calculate the number of aircraft movements and the amount of generated noise in the forecast year.

2.4 Iterative Procedure

If the total number of aircraft movements exceeds either the physical (runway) capacity or the legal environmental noise limit, an iterative procedure is started (Figure 5). In each iteration the airfares are increased by a scarcity charge (shadow cost), so that demand is reduced and airlines that fly with larger aircraft and/or from airports with less severe capacity constraints are favoured. In parallel, incentives for the airlines stimulate the use of larger and more modern (i.e. less noisy) aircraft. This iterative procedure is repeated until the demand fits the capacity.

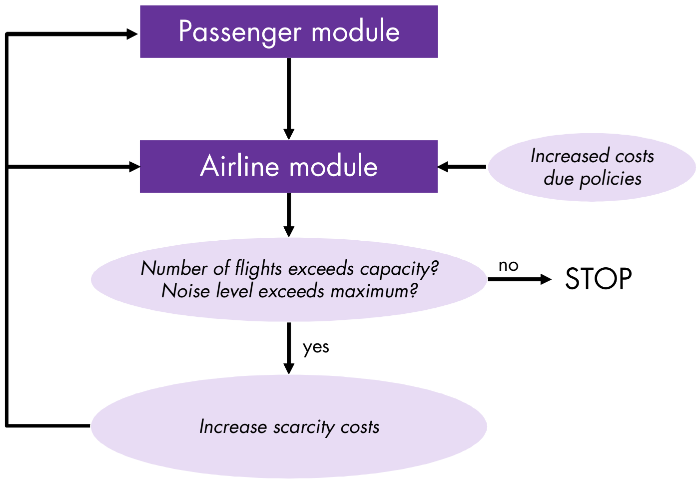

Figure 5: Iterative procedure

The user can choose between two options for the way the scarcity charges are allocated: free slot trading and a system with grandfathering rights. The first option allocates a charge to each aircraft movement, independent of airline. Since these costs are (partly) being transferred to the passengers by increased air fares, the final distribution of slots will favour those airlines (and those passengers) that have the highest willingness to pay for such a slot. This simulates a system of free slot trading where airlines may win and loose slots.

The second option keeps the number of flights per airline in the base year fixed. This means that slots that have been allocated to an airline in the past, can not be transferred to another airline (system of grandfathering rights). The remaining slots that were not allocated in the base year are distributed over the airlines proportional to their demand for extra slots. However, a small number of slots are given to the smaller airlines to simulate current policy to stimulate new entrants in the market.

In case of slot allocation the scarcity charge is (partly) dependent on the amount of noise that an aircraft generates in case the noise limitations are exceeded. This stimulates the choice for newer types of aircraft. In case of a slot allocation system with grandfathering rights there is no dependency of the scarcity charges on noise production.

The model also takes the runway capacity limits on Frankfurt and Paris Charles de Gaulle airport into account to prevent unrealistic predicted growth on these airports as a result of the limited capacity on Schiphol.

3. APPLICATION

The ACCM model has been developed and applied for the Dutch Ministry of Transport, Public Works and Water Management, under supervision of aviation experts from airports, airlines and economic research centres. This study (Veldhuis *et al.* 2005a, 2005b, 2006a, 2006b) investigated possible capacity problems for Amsterdam airport (Schiphol) projected for the year 2020 and 2040 based upon four different macro-economic and technological scenarios. The welfare effects were evaluated, and to mitigate the adverse societal effects a series of 14 different policy measures was investigated.

The results were used as input for the scenario policy assessment that the Ministry of Transport, Public Works and Water management together with other ministries (2006) recently completed on the future of Amsterdam Schiphol airport. This assessment was a key input to the new Dutch government policy decision concerning the future of the airport (Kabinetsstandpunt Schiphol 2006).

The scenario assessment is based on the four scenarios for the macro-economic future of the Netherlands that were developed by the Central Planning Agency (de Mooij and Tang, 2005). The implications of these four scenarios for air travel are displayed in Figure 6.

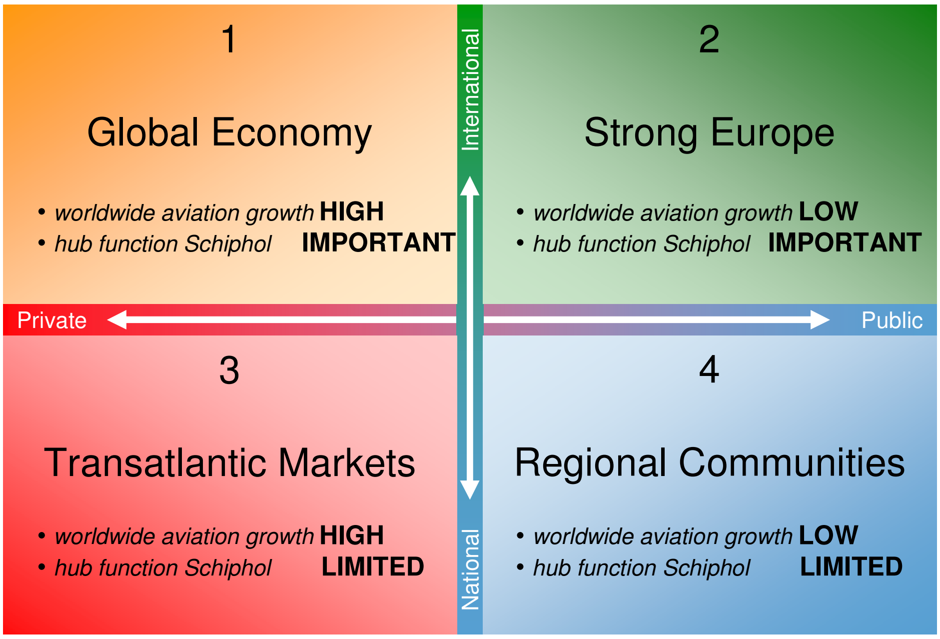

Figure 6: Four futures for air travel in 2020

Figure 7 shows the predicted numbers of flights in 2020 for all four scenarios in case of three assumptions

- no runway or noise restrictions (i.e. the potential unconstrained demand for air travel on Schiphol)
- the current policy scenario (i.e. with capacity constraints and with a slot allocation system based on grandfathering rights)
- an alternative capacity constrained scenario with a new slot allocation system based on slot trading.

For the high economic growth scenarios (global economy and transatlantic markets) the potential demand exceeds the existing capacity constraints, in particular the noise limits. It is clear that the system of free slot trading is more efficient in allocating flights within the capacity constraints, as significantly more flights can be accommodated. This is mainly due to the fact that this system has noise-generation dependent scarcity charges that stimulates the use of new and more quite aircraft.

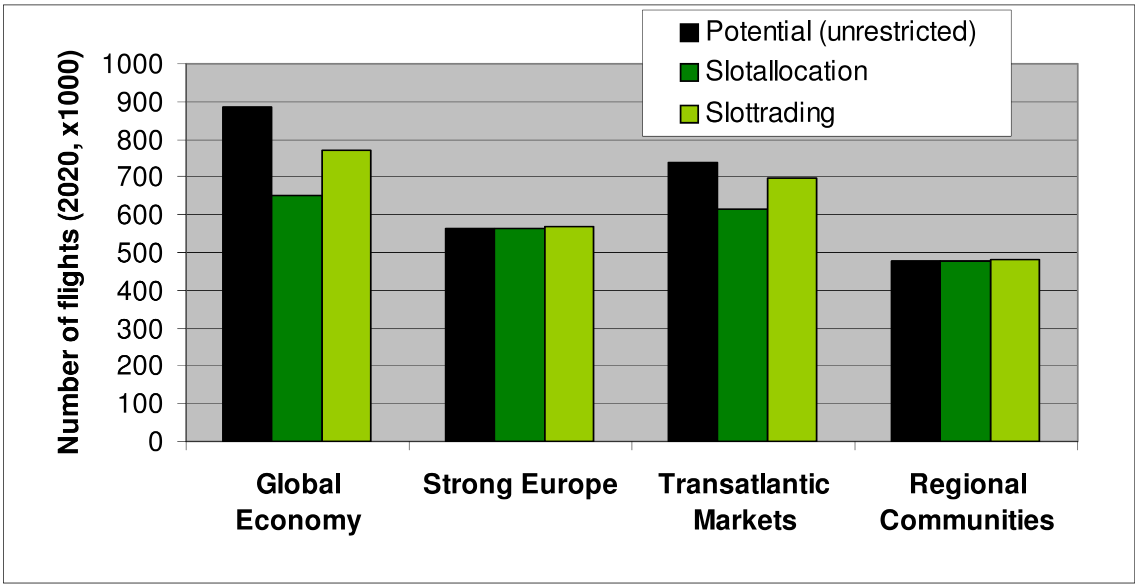

Figure 7: Model forecast of the number of flights per year in 2020 for the four scenarios for three cases (no capacity constraints, slot allocation based on grandfathering rights and slot allocation based on free trading)

In addition, we have calculated the effect of two types of policy measures. The first is a (budget neutral) levy scheme in which the oldest, most noisy aircraft pay higher airport taxes (increase of €20 per tonnes Maximum Take-off Weight (MTOW) compared to the current situation) while new aircraft pay less (decrease of €10 per tonnes MTOW). In the second scheme departures and arrivals in the evening period (19:00 – 23:00) are charged €10 per tonnes MTOW extra, while departures and arrivals in the night (23:00 – 7:00) are charged €40 per tonnes MTOW extra. Figure 8 presents the effects of these two policy measures in terms of number of flights per year for each scenario.

As can be seen from this figure, the number of flights that fits within the capacity constraints in the Global Economy and the Transatlantic Market scenario increases with the introduction of a charging scheme. As mentioned above, the growth in these scenarios is limited by the noise production constraints. Both charging schemes have a positive effect on the noise production per aircraft (either by stimulating the use of newer (and less noisy) aircraft, or by discouraging departures/arrivals in evening and (especially) during the night hours (since any noise produced during these periods of the day are given a higher weight (penalty) in the summation of the total amount of noise produced).

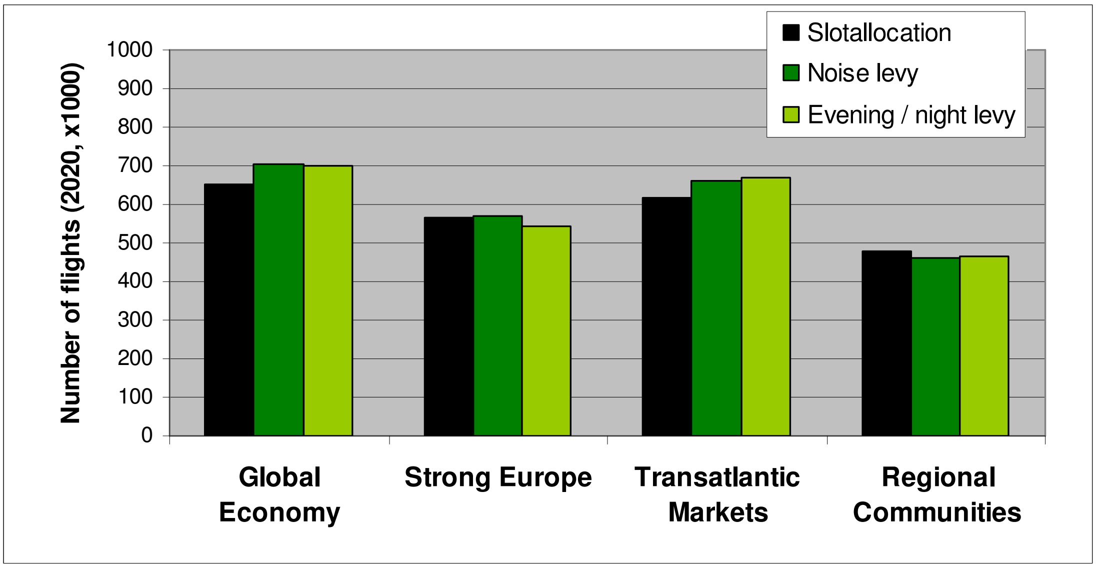

Figure 8: Model forecast of the number of flights per year in 2020 for the four scenarios for three cases: (1) slot allocation based on grandfathering rights (reference), (2) introduction of a charging scheme based on noise production, (3) introduction of a charging scheme based on time-of-day of departure/arrival)

In the other scenarios (Strong Europe and Regional Communities) the charging schemes have a negative effect, since the extra charges makes flying more expensive for travellers, resulting in a reduced willingness to fly. And there is no hidden demand (as a result of demand being larger than capacity limitations) compensating this effect.

Other charging schemes and policies that have been simulated are reported in Veldhuis et al. (2006b).

4. WELFARE EFFECTS

The welfare effect module of the ACCM calculates the consumer surplus for Dutch travelers. This includes also travelers that use other airports than Schiphol, so that any effects of e.g. capacity constraints at other airports are incorporated as well.

The consumer surplus is calculated using the logsum method (see de Jong et al. 2006 for an overview). The logsum is the logarithm of the sum over all alternatives of the exponents of the utilities and it is a measure of the expected utility from a choice from a set of alternatives. A person's consumer surplus is the utility (also taking account of the disutility of travel time and cost) that a person receives in the choice situation, expressed in money terms.

For a policy assessment it is important to look at the change of consumer surplus as a result of the policy compared to a reference situation. This reference situation is usually taken to be the current situation without any change in policy. For the ACCM the reference scenario is the slot allocation model with both the existing runway capacity (no extra runways) and the existing noise limitations.

We have calculated the consumer surplus changes for a range of fourteen different policies (Veldhuis et al. 2006b). Table 2 presents these changes for the four scenarios in case that an extra runway is built, the noise limitations are discarded, a system of slottrading replaces the current system of slotallocation (compare Figure 7) and if noise levies or evening/night levies are introduced (compare Figure 8).

Table 2: Change in consumer surplus for Dutch air travellers as a result of a policy (in million Euro) compared to the reference scenario (slotallocation)

	Global Economy	Strong Europe	Transatlantic Market	Regional Communities
Extra runway	-21	+26	-10	0
No noise limitations	+214	0	+185	0
Slottrading	+167	3	+171	+10
Noise levy	+86	+8	+106	-26
Evening/night levy	+91	-23	+132	-45

As can be seen from this Table, the construction of an extra runway does not lead to a (substantial) change in consumer surplus. This is due to the fact that in the Strong Europe and Regional Communities scenarios the growth of aircraft movements is not limited by the existing capacity limitations and in the Global Economy and the Transatlantic Market scenarios the growth is limited by the noise restrictions. According to these calculations, discarding the noise limitations has about the same impact on consumer surplus as the introduction of a slottrading system.

5. APPLICABILITY FOR OTHER AIRPORTS

Though this model was originally developed for Schiphol airport, the concept of the model is generic and can be adapted for application to other airports and other countries. The methodology is conceptually straightforward, and the application is well understood by policy makers.

An important requirement for the ACCM is the availability of data about the existing origin-destination profile of passengers using the airport under consideration (base-matrix). Often such information is readily available from airport surveys, but alternatively MIDT data bases can be acquired for this. Other important data requirements are capacity information, both concerning the physical (runway) capacity of the airport and the environmental (noise) capacity of the airport. This for the different hours of the day, and for both base year and planning horizon.

The transferability of the ACCM approach is currently being tested in an application in France. Although this application does not include the full traveller choice module, we are confident that this test will show how the concept can be successfully applied elsewhere.

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