THE INTEGRATED AIRPORT COMPETITION MODEL, 1998

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ABSTRACT

This paper addresses recent model development by the Directorate General of Civil Aviation (DGCA) and Hague Consulting Group (HCG) concerning long-distance travel. Long-distance travel demand is growing very quickly and raising a great deal of economic and policy issues. There is increasing competition among the main Western European airports, and smaller, regional airports are fighting for market share. New modes of transport, such as high speed rail, are also coming into the picture and affect the mode split for medium distance transport within Europe.

Developments such as these are demanding the attention of policy makers and a tool is required for their analysis. For DGCA, Hague Consulting Group has developed a model system to provide answers to the policy questions posed by these expected trends, and to identify areas where policy makers can influence the traveller choices. The development of this model system, the Integrated Airport Competition Model/Integraal Luchthaven Competitie Model (ILCM), began in 1992. Since that time the sub-models, input data and user interface have been expanded, updated and improved. HCG and DGCA have transformed the ILCM from a prototype into an operational forecasting tool.

INTRODUCTION

The growth of air traffic at Dutch airports is a hotly debated issue in current national politics. In particular, limits on the capacity growth of Amsterdam Airport Schiphol pose a major problem because of excessive demand. Recently the Dutch government made the decision to build a new (fifth) runway. The essential question now is whether Schiphol can handle the future growth within the agreed environmental restrictions or if a new airport is needed.

Another large transport infrastructure project is the construction of high-speed rail lines. The government recently made the decision to build one of these (between Amsterdam and Antwerp, connecting to Brussels, Paris and London), and others may follow. The government is currently in search of private investors in order to reduce the public costs of this new infrastructure. These rail lines will include a stop at Schiphol Airport and could have significant impact on long-distance travel flows to specific destinations. Policy-makers recognise that changes in one transport mode affect each of the others. This is due to competition as well as complementarity between modes. It is important to consider these interactions when developing new transport policy and planning tools.

The Integrated Airport Competition Model (ILCM) was developed in response to policy questions about the future of air transport in the Netherlands. It is based on several sub-models that act as building blocks for a comprehensive system. These sub-models correspond to each stage of the decision process for a long distance trip and include airport access mode choice, airport/air route choice, main mode choice, and trip frequency models. The airport/air route and main mode choice models have recently been updated and calibrated.

The current ILCM is the result of a continuous process of improvements of the prototype system that is described in earlier papers (Veldhuis, Bradley, Brouwer, and Kroes, 1995). This paper gives an overview of the model structure, the sub-models and some examples of possible applications of the system.

STRUCTURE

ILCM Behavioural Assumptions

Before a traveller undertakes a long distance trip, he or she makes a series of decisions. The ILCM assumes that a decision chain, illustrated in Figure 1, can reasonably represent these choices. Each decision in the chain is represented in the ILCM by a choice model.

- The first choice a potential traveller makes is whether to make the trip or not. This is represented by a *trip frequency model* in the ILCM.
- Next, he or she decides either to fly or to use another mode, such as car, train or coach. This is dealt with in the *main mode choice model*.
- If a traveller decides to fly, he can often choose either a direct flight or a route that involves a transfer. Related to this is the choice between different departure airports in the area. Each airport may have different accessibility, availability of parking places, frequency of flights, etc. This part of the system is called the *air route choice model*.
- Finally, the traveller can go to the airport by public transport, by taxi, by driving and parking at the airport, or be dropped off by friends, family or colleagues. This choice is represented in the *access mode choice model*.

In the ILCM, all these dimensions of the choice process are combined in a coherent manner. A change in the frequency of flights from a certain airport, for instance, can affect all choices in the decision chain, either directly (air route and/or main mode choice) or indirectly (access mode via the choice of another departure airport).

In order to model the choices of travellers potentially making use of Schiphol Airport, the ILCM includes a market area that extends beyond the borders of the

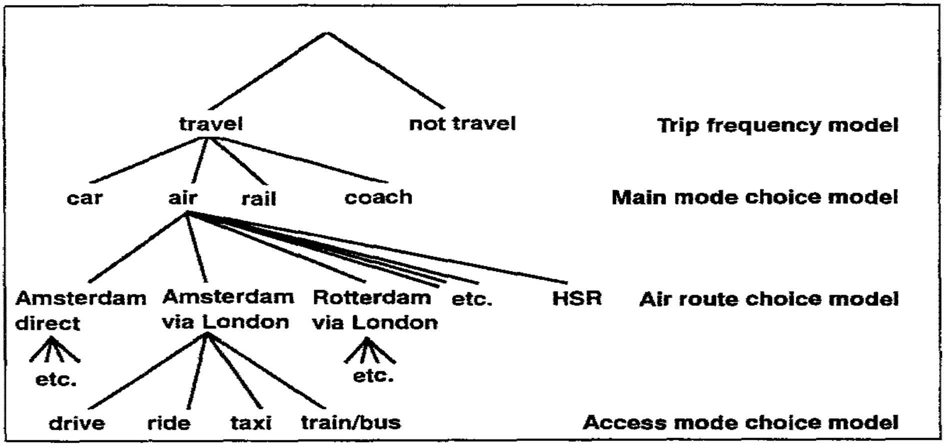

Figure 1. Decision chain for long distance travel

Netherlands to include Belgium and parts of western Germany. Brussels and Dusseldorf airports are likewise included as airports which compete for travellers with origins and/or destinations in the Netherlands.

The THEORY Behind the ILCM

The structure of the ILCM is based on the fact that a traveller has to make a series of decisions before he or she actually makes a long distance trip. These decisions are not independent. The ILCM is a combination of models such that the choice at a lower level will influence the choices at higher levels. This is modelled by a nested or tree logit structure. The theory behind this type of modelling is described in Ben-Akiva and Lerman (1985).

The basic assumption of multinomial logit models is that people choose the option, for example the access mode, that gives them maximum utility. For each available access mode, a utility function is determined. Utility functions are assumed to be of the form

$$U^{access}(i) = \alpha + \beta*Cost + \delta*Time + \varepsilon*Age + \phi*Sex + \eta*Travel\ Purpose + ...$$

The probability of choosing alternative i in Logit modelling can be written as:

$$P(i) = Exp(U^{access}(i)) \ / \ \Sigma_j \ Exp(U^{access}(j))$$

where U(i) is the utility function of alternative i and summation Σ_j is overall alternative j.

The person and travel characteristics which are to be included in the utility function are determined during the estimation process.

In the nested model structure (shown in Figure 1), each choice lower down the tree is conditional on the choice above it. The attractiveness of the alternatives for that choice also affects the choice that will be made above it.

The levels in the tree structure influence each other. Improvement of public transport access to regional airports, for instance, not only implies that more people who already travel via a regional airport will choose public transport as an access mode (direct effect). Also the number of travellers via regional airports will increase (first order effect), and to a lesser extent the number of air travellers overall will go up (second order effect).

This interaction between the choice levels is included in the model structure through so-called logsums. The logsum is a measure of the overall attractiveness of all alternatives at a given level of the tree structure and is computed as the logarithm of the sum of the exponential utilities:

$$\text{Log}(\Sigma_i \text{ Exp}(U(i))).$$

In the route choice model, logsums are included from the access mode choice model for each airport. Thus, the utility function for travel via Rotterdam airport, for instance is described as:

$$U^{route}(\text{Rotterdam}) = \alpha + \beta * \text{Log}(\ \Sigma_i \text{ Exp}(U^{access}(i))) + \delta * \text{Time} + \varepsilon * \text{Cost} + \ldots\ldots..$$

where (i is over all access mode and $U^{access}(i)$ is the utility of travelling to Rotterdam airport using access mode i. Thus, if public transport access to Rotterdam airport is improved, $U^{access}(i)$ increases for i=public transport; consequently the logsum for access to Rotterdam goes up, which increases the value of U^{route}(Rotterdam).

The interaction between the main mode choice model and the air route choice model is taken care of in the same way. Logsums are used for travel via all airports and using all available air routes, giving a utility function for air travel:

$$U^{main}(\text{Air}) = \alpha + \beta * \text{Log}(\Sigma_i \text{ Exp}(U^{route}(i))) + \delta * \text{Time} + \varepsilon * \text{Cost} + \ldots\ldots..$$

In this application, Σ_i is over all air routes and $U^{route}(i)$ is the utility of travelling by air via route i (including departure airport choice). This means that if (for instance) tickets via Maastricht airport become cheaper, travel to all destinations by way of direct and indirect flights from U^{route}(Maastricht) becomes more attractive. Also, if (for example) tickets with a transfer at London are sold at lower prices, air becomes more attractive through U^{route}(via London) for all departure airports and all final destinations. In the previous example where public transport access to Rotterdam airport is improved, U^{route}(Rotterdam) increases and thus U^{main}(Air) also goes up.

The final interaction is that between the total number of trips and overall attractiveness of all main modes. The choice between travelling or not travelling is at this phase of the ILCM not made through logit modelling. The current ILCM models frequency by use of a fixed elasticity-based model that includes an elasticity for generalised cost.

$$\text{Log}(\Sigma_i \text{Exp}(U^{main}(i)))/\varepsilon$$

where Σ_i is over all main modes, $U^{main}(i)$ is the utility of main mode i and ε is the main mode choice model cost coefficient ($\varepsilon < 0$). Improved overall accessibility (e.g. through the introduction of high speed rail, more frequent flights etc.) means that the generalised cost of travel decreases since $\varepsilon < 0$. The elasticities therefore have the same sign as the cost coefficient to assure that a higher attractiveness of travel means that the number of trips increases. An elasticity value of -0.3, for example, means that if the generalised costs increase by ten percent, the number of trips decreases by three percent. Another element of the frequency model is growth based on economic variables.

Recalling the example of improving access to Rotterdam Airport, this would decrease generalised costs through higher values of U^{access}(Access), U^{route}(Rotterdam) and U^{main}(Air), respectively. It is important to realise that the influence of a change at a certain level of the decision chain has the largest influence on the choice made at that level. The effect on higher level choices decreases with each step higher in the chain. Thus, improvement of public transport access to Rotterdam airport has the largest effect on access mode choice to Rotterdam airport, a smaller but usually measurable effect on the number of trips via Rotterdam airport, an even smaller effect on the number of air trips overall. The least amount of effect will be on the number of long distance trips made by all modes.

The models were estimated separately starting at the bottom of the tree (see Figure 1) with the access models. The process of finding the optimal set of parameters is carried out using HCG's estimation package ALOGIT. Various data sources were used for this estimation. These are described in later sections of this paper.

Descriptions of the Models

Access Mode Choice Models. The airport access mode choice models were estimated based on the actual choice observed in the 1991 Schiphol survey data. For the estimation of access mode choice models for travel to the airport, nine different segments were distinguished, each having their own typical travel behaviour. Five categories were developed for residents (those living in the hinterland of Schiphol) and four for non-residents.

Hinterland residents (Benelux and west of Germany):	*Other travellers from Europe/ICA:*
Business (trips longer than 2 days)	Business (trips longer than 2 days)
Short Business	Short Business
Vacation	Vacation
Other Purposes	Other Purposes
Charter	

For each of these segments, separate access mode choice models were estimated. In the access mode choice models, four mode alternatives were included.

They differ by residents and non-residents.

Residents:	*Non Residents:*
Car Drop-off (car passenger)	Car Drop-off
Car Parked (car driver)	Rental Car
Taxi	Taxi
Public Transport/high speed rail*	Public Transport/high speed rail*

*airport access by high-speed rail (HSR) is only possible for specific airports when main mode choice is air.

The most important variables in the choice between modes are usually travel cost and travel time. All costs in these models are based on distance except for parking, which is based on duration of stay at the destination. The costs of a rental car are not included, since it is assumed that the car will mainly be used for trips other than to and from the airport. The main explanatory variables are the following.

- *The number of flights a traveller has made during the previous months* has a negative influence on the choice of the car passenger alternative and a positive influence on the taxi and car driver alternatives.
- *Flying to an intercontinental destination or staying away a large number of days* has a negative influence on the choice for train. Too many bags to carry might be the underlying reason. For the choice of car drop-off, this influence is positive.
- *Women are less likely to use a car* and, for the short market segments, more likely to be dropped-off at the airport than men.
- *There is a strong dependence between age and the use of taxi.* The older the traveller, the more likely that he or she will travel to the airport by taxi. This effect is especially significant for the non-business segments. People over 50 are relatively often taken to the airport. People under 30 are more likely to use train and less likely to use car.
- *Scandinavian visitors use taxi relatively often.* Visitors from the United Kingdom, however, are more likely to use train. Taxi is more likely to be used by business travellers.

The values of travel time inferred from the estimated model are quite high for both business and non-business travellers. This result is typical for airport access models, since the cost of the access trip is quite small compared to the potential cost of being late for the flight.

Air Route Choice Models. This model assumes that the destination airport is fixed and predicts the choice of air route to that destination, including the choice of departure airport and possibly a transfer airport. Because there was no data available in the Netherlands to estimate such a model, a stated preference survey was carried out in 1992 at Amsterdam, Eindhoven and Brussels airports. The survey provided data to estimate models of the choice of departure airport and air route (direct vs. transfer) as a function of fare, frequency, travel time, access time, etc. In the SP route choice data, respondents often had the choice between travelling from the actual departure airport or switching to an alternative airport to take advantage of a better or cheaper flight. The SP experiment and analysis are described in some detail in Bradley (1994).

Although we expect the SP data to give the best estimates of the **relative** importance of the variables (e.g. fare versus frequency), SP and RP data typically show different **overall** sensitivities (the scale of the coefficients), as well as different residual constants. It was therefore necessary to calibrate the models as much as possible to RP route choice data.

The access mode choice models are linked to the route choice models by a logsum variable that is the composite utility of access to a given airport across all available access modes.

Air route choice models were estimated for seven different market segments. Both business and non-business segments are split into short (major nearby destinations such as Paris, Frankfurt, London, Manchester and Copenhagen), the rest of Europe and intercontinental (ICA). Charter trips form the seventh segment.

The main variables in the model are:

- *Fare:* A linear coefficient per guilder, highly significant in all the models. The coefficient tends to decrease with journey distance, but is always 3 to 4 times as high for non-business as for business. The charter coefficient is even higher still when compared to the non-business Europe coefficient.

- *Frequency:* The logarithm of the frequency per week. For transfer routes, the lowest frequency of the two flights is used. The effect is strongest for the shortest routes, and stronger for business than non-business — particularly relative to fare.

- *Journey time:* The in-flight time plus 3 times the transfer wait time. Because there was not enough variation between flight times in the SP data to estimate a significant effect in most of the segments, the ratio of 1 to 3 was determined from the segments where an effect could be estimated (i.e., the transfer wait time is perceived to be 3 times as onerous as in-flight time). This is also similar to the ratio often estimated for wait time relative to in-vehicle time in other modes. For the short and charter flights, no effect could be estimated. For the other segments, journey time is more important for business than for non-business.

- *Transfer dummy:* Transfer routes are significantly less preferred than direct ones, even after accounting for the in-flight and wait time differences. The effect is only slightly higher for business than for non-business.

- *Airport constants:* Since we are using SP data from a choice-based sample, the constants will need to be recalibrated, so the results here are not critical. The constants for the various airports relative to Schiphol are not significant in most cases, and do not show any marked trend across the segments.
- *Access model logsums:* For application, all logsum coefficients should be in the theoretically valid range of 0 to 1.0. For some segments, the logsum coefficient had to be constrained to 1.0.

Our survey sample contains 985 observed choices of airports and air routes. Using those choices, an RP model was estimated of the choice between a direct or transfer route from either Amsterdam, Eindhoven or Brussels airport. In addition, information on passenger volumes at the different airports within the Hinterland was used to ensure a realistic distribution of passengers among these airports. This information was provided by DGCA and the Contraal Bureau voor de Statistiek (CBS) report *'Statistiek van de Luchtvaart'* (1994).

The airport/air route models were adjusted at several levels prior to implementation. The models for the Business Short and Non-business Short segments do not have coefficients for journey time or transfer dummy. No observations in these segments transferred during their trips by air, which is to be expected, and so no transfer dummy could be estimated. While an effort was made to estimate journey time coefficients for these segments, the results were not significant. It is desirable to include journey time and a transfer dummy in these models so that future policy and network changes have an effect on air travel in these segments. Therefore, in the ILCM application, the values of time estimated in the Business Europe and Non-business Europe segment models were used together with the fare coefficients in the Business Short and Non-business Short segments to estimate journey time coefficients. Similarly, the values of transfers in the Europe segments were used to estimate transfer dummies for the Short segments.

Main Mode Choice Models. In 1995 HCG investigated a source of information called the European Travel Monitor (ETM). The ETM is a collection of different surveys across Europe and includes trip-level information across purposes, travel modes and destinations. Because of inconsistencies between these surveys and the very high cost of the data, HCG and DGCA obtained only the data concerning long-distance trips made by residents of the Netherlands in 1994. In theory the ETM files obtained by HCG include a representative sample of these trips. Because of serious interpretation problems it was not possible to determine the proper weighting of the records. However, there were enough unweighted observations to proceed with estimating main mode choice models.

As described earlier, the access models are linked to the route choice models, and the route choice models are linked to the main mode choice models. The link from the route choice models to the main mode choice models consists of a logsum term for the airport/air route choice.

Separate main mode choice models were estimated for four market segments:

- Business Short: business trips to London, Paris, and nearby portions of Germany;
- Business Europe: business trips to the rest of Europe;
- Non-business Short: non-business trips to London, Paris and nearby portions of Germany; and
- Non-business Europe: non-business trips to the rest of Europe.

These are the same market segments for which airport/air route choice models were estimated, with the exception that no models were estimated for business or non-business travel to intercontinental destinations. The reason for this is that travellers to these destinations are assumed to have no main mode choice: they must travel by air.

Four main mode alternatives are offered:

- air or HSR (highly competitive, high quality connections);
- train (low comfort level);
- car; or
- coach.

Some assumptions had to be made to incorporate the attractiveness of charter flights into the models, because it is not clear when the air alternative is charter for a given destination. According to the Schiphol survey, the main charter destinations are Spain, Portugal and Greece. For estimation purposes it was assumed that all non-business trips to these destinations fall under the charter route choice segment. A separate logsum coefficient for charter was necessary to deal with the fact that the charter and scheduled air route choice logsums are of different orders of magnitude.

Almost all of the important destinations in Europe for trips from the Netherlands have unique characteristics that are determining factors for mode choice. Because the UK is an island, a much larger share of trips with UK destinations use air as main mode than might be expected on the basis of distance. France is an important destination for particular types of holidays, such as camping. This is reflected in the dominant use of the car as main mode. Car is more important for very long distance trips (to southern France, for example) than might be expected. Non-business trips to Switzerland and Austria are clustered in the winter, which is to be expected. Again more of these trips are made by car than would be expected on the basis of distance. It may be that because winter destinations tend to be far from airports and that a high number of local train transfers are required (with sports equipment being carried), many travellers choose to use a car.

The main variables in the main mode models are the following.

- *Air route logsum:* Theoretically for application the logsum coefficient should be in between 0.0 and 1.0. For non-business the coefficient is lower than for business.
- *Cost:* A linear coefficient per guilder. Highly significant for non-business purposes.
- *Travel and wait time:* For non-business short the wait time coefficient is 2.5 times the travel time coefficient. For longer distances this ratio is 6.3 for non-business and 10.0 for business. For business short the ratio is set to 3.0 because it was not possible to estimate a separate wait time coefficient.
- *Duration variables:* For longer trips car is more likely to be taken, because of multiple destinations. For business trips shorter than six days, air is more likely to be chosen. Bus is less attractive for business trips shorter than three days and holidays longer than two weeks. This has to do with the amount of time and comfort relative to the duration of the trip.
- *Season:* Car is more likely to be taken in summer. For non-business air is less likely to be taken in summer for European destinations and bus less likely in the winter.
- *Age:* As expected younger and older people tend to use more public transport than cars.
- *Long distance:* For non-business Europe shorter than 750 km car is more likely. This are people travelling from the southern Netherlands. For non-business short the train is less likely above 750 km.

The low number of business observations in the ETM resulted in statistically weak time and cost coefficients for the business segments, but these still provide acceptable values of time.

Table 1
Main Mode Values of Time

Segment	*time coefficient*	*cost coefficient*	*value of time*	*number of observations*
Business Short	-0.001755	-0.002788	f 37.77	275
Business Europe	-0.002143	-0.002317	f 55.49	258
Non-business Short	-0.004176	-0.010160	f 24.66	2119
Non-business Europe	-0.002413	-0.005874	f 24.65	7028

Calibration of the Model System. The Schiphol Survey is used as the main source of data for the ILCM. This survey contains some 100,000 interviews per year amongst all passengers departing from Schiphol, including transfer and charter passengers. As this survey contains only air trips from Schiphol, this data could not be used in the ILCM directly to provide a representative sample of all long distance trips. Therefore, the ILCM model system creates a synthetic database based on the Schiphol Survey.

The creation of the synthetic sample was done using the models that are implemented in the ILCM to infer the number of relevant trips not observed in the Schiphol Survey. The underlying assumption is that if for a certain trip from a known origin and to a known destination, the model gives probability α of using air from Schiphol, this trip represents $1/\alpha$ trips between this origin and destination departing from all airports and using all modes. If, for instance, 100 vacation trips are observed between Gouda and Marseilles departing from Schiphol, and the model gives probability 0.25 that such a trip will go by air from Schiphol, we can infer that there have been 400 trips in total from Gouda to Marseilles. Of those, 300 are either using another airport or going by road or rail. The redistribution of these remaining unobserved trips is also done using the probabilities from the ILCM models.

Problems with the ETM data made it impossible to estimate models using weighted, expanded observations. In addition, lack of data necessitated using the same models for residents of the Netherlands as for non-residents. As a result, extra calibration of the main mode models was required in order to obtain a realistic base year main mode split.

This calibration is based on three data sources:

1. *Prognose des Personenverkehrs in Europa bis zum Jahr 2005*, tabellenband (IFO Institut fr Wirtschafstsforschung, (1996);
2. *Vakantie van Nederlanders 1996* (CBS, 1997); and
3. *Buitenlandse toeristen in Nederland 1993/1994* (CBS, 1995).

The calibration data sources show that residents of the Netherlands and residents of other countries do not have identical main mode choice behaviour. Because we use the same main mode models for residents and non-residents, it was necessary to introduce an extra penalty for all non-Hinterland production zones in Europe (except in the case of UK and Ireland).

During calibration it appeared that the main mode models for business purposes, when compared to the non-business models, had unexpectedly high train and/or coach shares for Switzerland/Austria, Spain, Portugal and Italy, which needed to be corrected.

In particular, the mode shares for the destinations Denmark, Switzerland/Austria, Portugal and Greece are quite different in the calibrated results.

Germany: The targets from the available data sources could not be used directly, because a part of Germany is Hinterland and can not be seen as a destination.

France: According to the two CBS data sources, residents of France travelling to the Netherlands have a significantly different mode split from residents of the Netherlands travelling to France. In particular, the air mode has a much higher share among French than among Dutch residents.

Table 2
Main Mode Choice Final Calibrated Model (by percentage*)

Destination	*Air*	*Car*	*Train*	*Coach*	*Total*
Germany	16.2	66.6	7.7	9.4	99.9
UK	45.0	35.3	8.6	11.2	100.1
Ireland	82.6	13.7	1.7	2.0	100.0
France	10.2	63.8	9.5	16.4	99.9
Denmark	54.2	39.2	1.9	4.6	99.9
Sweden/Norw.	64.3	22.9	5.0	7.8	100.0
Finland/Ice.	72.6	21.4	0.4	5.5	99.9
Switz/Austr.	20.8	57.6	6.0	15.6	100.0
Spain	53.4	22.5	3.2	21.0	100.1
Portugal	83.1	8.3	0.8	7.8	100.0
Italy	37.4	36.6	10.0	16.0	100.0
Greece	86.0	6.0	5.9	2.1	100.0
SE Europe	72.8	17.0	3.3	6.9	100.0
East Europe	36.7	45.8	5.5	12.0	100.0
ICA	100.0	0.0	0.0	0.0	100.0
Total	46.3	37.0	5.8	10.9	100.0

*Totals may not equal 100.0 percent due to rounding.

Scandinavia: The uncalibrated models did not adequately reflect the very high air share for these origins/destinations which appears in all three calibration data sources.

Switzerland/Austria: The uncalibrated models underestimated the air share to these destinations, largely because the ETM sample included a large number of winter holiday travellers to these countries going by car. This was not a good representation of non-Dutch residents from this zone travelling to the Netherlands.

Italy: The high mode share of train and coach was caused by trips from non-Dutch Hinterland origins, i.e. Belgium and Western part of Germany.

Trip Frequency Models. The market growth models in the ILCM are based on general economic indicators, changes in the level of service (defined as the sum of the utilities of the main mode model) and an exogenous trend. Four market segments are defined:

- business direct and negative transfer
- non-business direct and negative transfer,
- business positive transfer, and
- non-business positive transfer.

The market growth model is multiplicative and consists of the following factors:

- *Change in generalised costs:* growth factor $= (e^{(\text{new logsum} - \text{base logsum})})^{\text{elasticity}}$.

- *Income growth:* (for non-business) expressed as an index, based on the input GDP growth over the base year for the given scenario.
- *Trade growth:* (for business) expressed as an average index for the production and attraction side of the journey.
- *Exogenous trend:* expressed as an index.

The elasticity for generalised costs and trade growth can easily be changed with the user interface. The default generalised cost elasticity is set to 0.1 for non-business and 0.0 for business. These values are based on experience with other models developed by HCG, but sensitivity tests of the ILCM were used to determine them.

In the current version of the ILCM, the positive transfer market has a choice of air and combined HST/air routes. Positive transfer passengers are not permitted by the ILCM to choose transfer airports other than Schiphol, or to travel by modes other than air. One of the results of this structure is that, given the current market growth models, any change in air level of service can result in extreme changes in the size of the positive transfer market. For this reason we have not included generalised cost in the positive transfer market growth calculations.

The business elasticity with respect to trade was estimated to be approximately 0.8.

The DGCA provided income elasticities for various time periods based on a standard Euro 1 scenario.[1] The income elasticities are not applied exactly as they appear in Table 3. A single income elasticity value is used. This single elasticity is calculated as follows.

1. An income elasticity is calculated for each year between 1990 and 2030 by interpolation based on the original values shown in Table 3.
2. The ILCM base year is 1994 and the new ILCM forecast year is 2020; a single income elasticity for the period 1994-2020 is calculated by averaging the interpolated values across the period 1994-2020.

Table 3
Income Elasticities for Euro 1 Scenario

	1990	*2015*	*2030*
Eur- Eur	1.35	0.9	0.7
Eur- ICA	2.5	1.35	1.1

The average income elasticity for 1994-2020 that is applied in the ILCM is **1.04** for intra-European travel and **1.71** for Europe-ICA travel. This elasticity is applied to the total income growth over the entire forecast period.

HIGH-SPEED RAIL IN THE ILCM

High-speed rail (HSR) has an impact on the travel choice on two levels: as an access mode and as a main mode. As an access mode, HSR is treated as a fast train. Introducing HSR as an alternative means that the access by train to relevant airports improves. HSR can be used as an access mode from specific zones to four airports in the ILCM: Schiphol, Brussels, Dusseldorf and Antwerp. As a main mode, HSR is included as a separately defined, high quality travel alternative.

During the course of ILCM development, there was much discussion by HCG and DGCA about exactly how high speed rail should be incorporated in the model system. Evidence from other studies indicates that there is much stronger competition between HSR and air travel than between HSR and any other mode.[2] In addition, several studies have incorporated the idea of air-rail integration. This integration entails a single-ticket trip made by a combination of HSR and air with a seamless transfer at a HSR station located at an airport. Integration means that the traveller experiences no difference in service level (reservations, baggage handling, etc.) between the HSR portion of the trip and the air portion. In other words, the HSR segment of the trip is the same as the segment travelled by airplane, except that the HSR travels on the surface. The HSR travel time is also comparable to air travel time for many destinations when considering the high speed together with shortened access/egress time.

The ILCM includes HSR as a main mode by considering HSR routes to be alternative air routes. This means that HSR is treated as an extension of the air mode. No explicit choice between HSR and other modes takes place in the main mode models. Instead, the determination of whether a trip is made by HSR depends on the route choice.

Three types of HSR connections are incorporated in the ILCM:

- a trip made with a direct HSR route without any transfer,
- a trip made by HSR with a transfer from one train to another (longer distance), or
- a trip made using a combination of HSR and air segments.

The origin and destination of a given trip determine the availability of HSR as a route alternative. For example, from Amsterdam to Paris, HSR may be an attractive alternative. A person making a trip from Amsterdam to New York could take HSR to Paris and fly from there to New York. It is unlikely, however, that someone would take HSR to Paris and then fly to Marseilles. In the current version of the ILCM, HSR may be used as the main mode for trips with destinations in Europe. The combination for HSR and Air is only available for intercontinental trips. For each destination only one HST or HST/Air alternative route is modelled.

The incorporation of HSR into the airport/air route choice model entails not only the use of a file of HSR routes but also the definition of 8 extra "ports", or HSR stations. Each origin zone has access to a maximum of three HSR stations (including possible HSR stations at selected airports). Depending on the corridor of the destination, South, East or North, one HSR station is selected.

Positive transfer trips, which have origins and destinations outside the Hinterland but transfer at Schiphol may use high-speed rail for one part of their routes. In the ILCM, the choice between air routes and HSR routes for positive transfer trips is determined by the route choice models. While the introduction of new HSR routes, as well as new air routes, could change the transfer location of the positive transfer trips (from, say, Schiphol to Frankfurt), the current version of the ILCM does not model this. The change in competition between airports is not part of this model. The positive transfers in the ILCM are based on 1994 information from the Schiphol survey. The only changes to these trips in the ILCM are made in the market growth model, based on economic changes, and route choice models.

In the ILCM, positive transfer trips are constrained to using Schiphol. One result of this is that they can only use HSR if they transfer at Schiphol, also for direct HSR connections. This is a limitation placed on the ILCM to avoid processing large and complex air and HSR networks and may be removed in future versions of the system.

For transfers originating outside Europe with destinations outside Europe, HSR is not an option. The market growth model is executed for these trips, but not the route choice model.

THE ILCM IN DETAIL

Market Definitions

The main area of interest for Dutch policy makers is, of course, the demand for use of Dutch airports. The passenger markets for Schiphol and the regional airports of Rotterdam, Eindhoven and Maastricht form the context in which the model system is developed. HCG and DGCA recognised that the catchment area for these airports does not consist solely of the Netherlands, but stretches beyond country borders.

Three different areas were identified for the model system.

- Twenty-eight zones in the Hinterland, which is the area from which Dutch airports can reasonably be used as ports of departure for residents and visitors. It contains the Benelux and the western parts of Germany. In addition to the four Dutch airports, three competing departure airports in the hinterland are taken into account: Brussels, Antwerp and Dusseldorf.
- Twenty-two zones in the Rest of Europe can be reached from the hinterland by air and by the competing land modes. The full model structure applies here. Important European airports such as London, Paris and

Frankfurt are not considered as possible departure airports, but are taken into account as possible transfer airports en route.

- Fifteen zones in the Rest of the World can only be reached by air from the hinterland, and thus the main mode choice model is not relevant for these areas. The choice of air route is more often an important issue for intercontinental travel. One can often reach these destinations either via the main European airports or via other key hubs such as New York or Singapore.

TRAVEL INCLUDED IN THE ILCM

Travel between the origin zones in the hinterland and the destination zones outside the hinterland is represented in the ILCM, along with travel from origins outside the hinterland to destinations within. Shorter trips with both origin and destination within the hinterland are excluded — these trips generate very little air travel. Some trips with both origin and destination *outside* the hinterland can be important for the hub airports; these transfers account for a substantial fraction of the passengers using Schiphol airport. The transfer market is included in the ILCM but the choice behaviour of this market is not modelled as completely as that of the non-transfer market.

Transfer trips can be split into two categories: positive transfers and negative transfers. Positive transfers are made by passengers originating outside the Hinterland, changing planes at Schiphol, and continuing on to a destination outside the Hinterland (Europe or ICA). Negative transfers are defined as trips made by passengers originating *inside* the Hinterland, changing planes at an airport outside the Hinterland (other European zones) and continuing on to a destination outside the Hinterland (Europe or ICA), *when a direct route from the Hinterland to the destination exists.*

The specific types of travel alternatives included in the ILCM are outlined in Table 4.

Table 4
Hinterland-Europe/ICA Alternatives

Alternative	*Access Mode*	*Departure Airport*	*Transfer Airport*	*Main Mode*
Direct Air	*	*		
Indirect Air	*	*	*	
HSR / Air	*	**	**	*
HSR	*	**		
Train				*
Coach				*
Car				*

* Predicted by the ILCM
** The HSR route alternative is pre-defined Departure Port in Hinterland, Transfer Port outside Hinterland

Table 4 shows that a long distance traveller can choose between either a land mode or an air mode. In the future it is expected that HSR will allow convenient transfer to air at the major Western European airports, so it is treated as an air mode for our purposes. For all air modes, a traveller can choose between different access modes to get to the departure airport, which is one of the airports in the hinterland. For HSR, which in the ILCM has a limited number of departure stations, an access mode is also predicted in the decision chain. An air and/or HSR traveller can either travel directly (by air or HSR) or indirectly via a transfer airport. This is predicted by the air route choice model. For modelling purposes, we currently assume that the transfer airport is outside the hinterland, although in reality a small number of Schiphol passengers do change flights at Brussels or Dusseldorf, both of which are in the hinterland. The large majority of transfers, however, are via hub airports such as London, Paris, Frankfurt, Copenhagen and Madrid.

Note that at the destination end of the trip, the choices of arrival airport and egress mode are not modelled. Although these are also decisions that the traveller may have to make, they are not very relevant for local policy purposes. Also note that the models deal exclusively with outbound trips leaving the hinterland, although the ILCM does take into account whether those trips are made by residents or by visitors returning home. We implicitly assume that the choices for the inbound trips are symmetric, i.e. that the traveller will return by the same mode, and that an air traveller will return to the same airport.

INPUTS TO THE ILCM SYSTEM

Used in this way, the model system is essentially a pivot point procedure that predicts changes in demand for Schiphol Airport. It can also provide estimates of changes in demand for competing modes and airports, but these will clearly be less accurate than those for Schiphol for which we have accurate base data.

In addition to the demand database, the supply side inputs are very important for the model system to function properly. These inputs include travel times, distances and, for some modes, cost and transfers between origins and destinations. For the development of the ILCM, several data sources were used. Access mode travel times and distances to airports were derived from the National Model System (LMS). For road and rail in Europe, new European main networks were created to derive shortest paths. For air travel times and frequencies, the ABC Guide database was used that contains details for all scheduled flights serving the possible departure and transfer airports. Air fares were based on regression equations derived from a sample of actual fares. The main variables in the regressions are distance and fare class, with some variations allowed by destination region (e.g. higher fares to Scandinavia).

For the HSR a kind of default level of service is created. This means that the travel times are based on a full operational HSR network, the frequency is set to ten times a day and the prices are set equal to the air fares. From this point by the user interface it is easy to define specific scenarios. Fare changes can be made for combined HSR/air travelling separate from the air fares. Assumptions have been made about HSR check-in and transfer times in combination with air travel. For within Europe, check-in time for HSR trips is set at five minutes except for UK destinations, for which a 30-minute check-in is required (more restrictive border controls). Transfer times are equal to check-in times. For Hinterland-ICA combination routes, check-in is set at 90 minutes and transfer to air at 60 minutes. This compares with 60 and 120-minute check-in times for air within Europe and to ICA zones, respectively. Air-to-air transfer time is 60 minutes. While integration of ticketing between HSR and air is implicit in the assumption of interchangeable routes, no special integration of trains with airline check-in is assumed.

THE ILCM USER INTERFACE

HCG has developed a new ILCM user interface based on the specifications provided by DGCA (Jan Veldhuis). The ILCM user shell has been developed to allow users of the ILCM to perform the following functions:

- specify two types of modifications to model inputs: scenario changes and policy changes;
- apply (run) the model system; and
- view output results in the EXSYS program.

The structure from the user's perspective is shown in Figure 2.

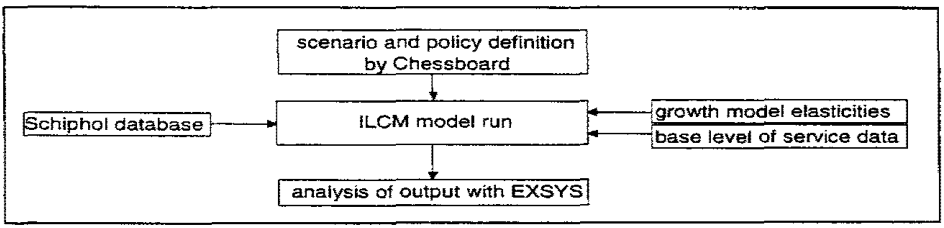

Figure 2. ILCM application structure

For the scenario specifications the Chessboard (see Figure 3) allows the user to specify aggregate or disaggregate changes on the main level of service variables. The user modifications of these variables are organised into two categories: scenario changes and policy changes. Scenario changes are meant to be background changes in economic growth and national transport regulations, while policy changes are meant to be policies implemented directly by the user of the ILCM (such as DGCA). Policy changes can also be specified as additional tests beyond the changes in a standard forecast such as 'Global Competition' (Central Planbureau, 1997).

The tool to analyse the result of ILCM runs is called EXSYS. With Exsys it is possible to compare different scenarios in a standard way. In addition to tables, it is possible to create graphical output in EXSYS. This may be in the form of bar or pie charts as well as in the form of simple maps. Below two examples of EXSYS graphics output are shown.

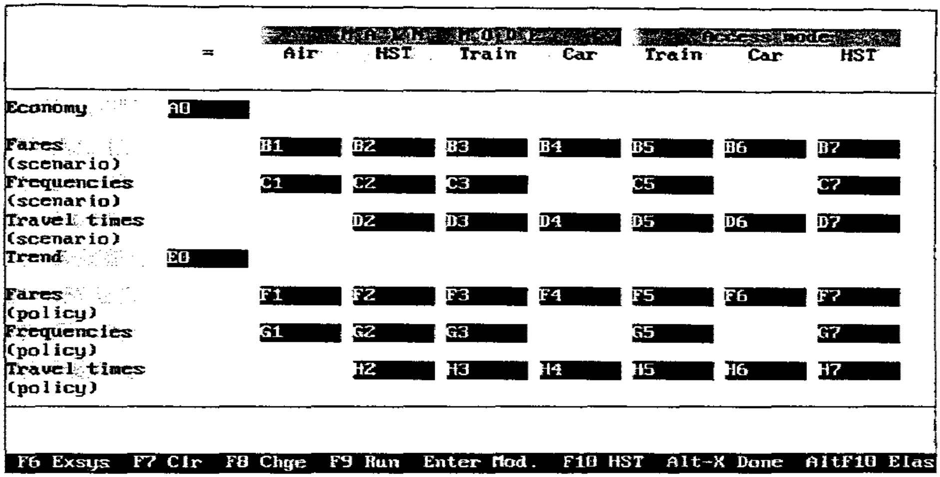

Figure 3. Chessboard

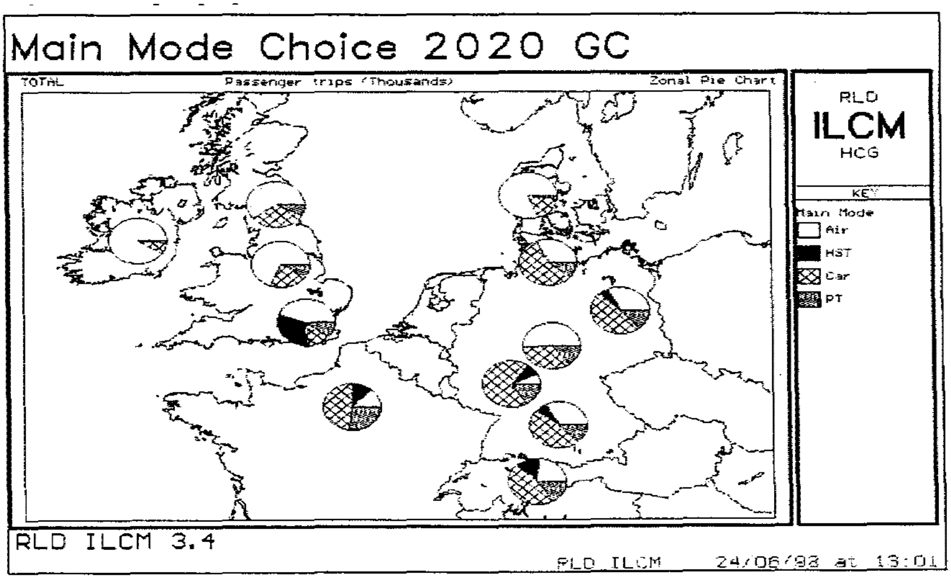

Figure 4. Output graphic of the ILCM

The graphs shown here are based on the Global Competition forecasts made for the Centraal Planbureau (1997). Three different scenarios were defined: Divided Europe, European Co-ordination and Global Competition. This resulted in forecasts for passengers from Schiphol and HSR-substitution of between 57 and 90 million and 3.8 and 6.4 million trips, respectively. The graph in Figure 5 shows that there are also HSR travellers attracted from car and train modes. The bars in the second graph show, respectively, the Global Competition scenario without HSR and with HSR East and South fully available for relevant destinations. The German and French destinations are aggregated.

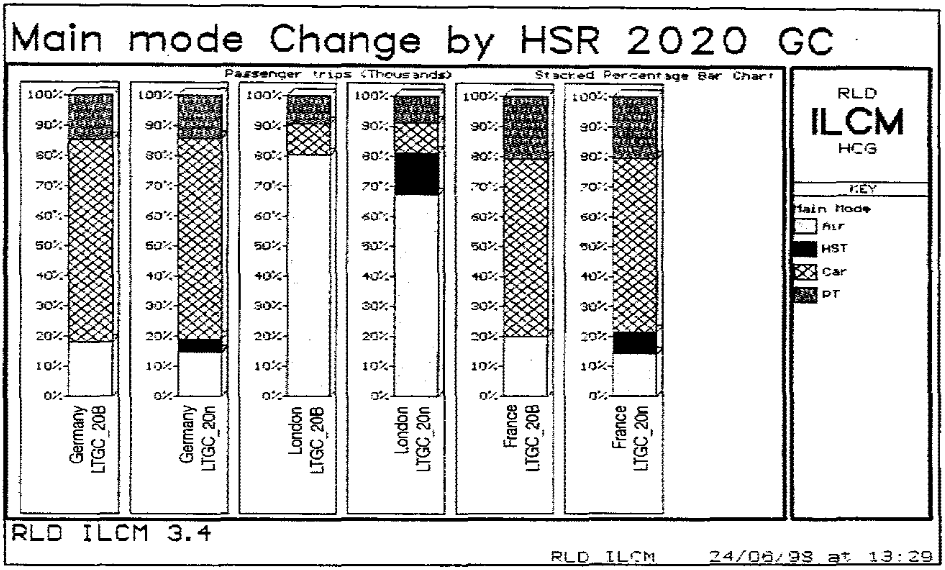

Figure 5. Output graphic of the ILCM: Main mode choice for trips with Dutch origins

FUTURE MODEL DEVELOPMENT

The ILCM provides analysis of Amsterdam Airport Schiphol in relation to surrounding, competing airports and competing surface travel modes. While it is highly developed in terms of estimating total passenger travel demand, main mode choice and air route choice, it does not yet provide any information relating to freight. The ILCM's demand forecasts are not capacity-constrained, nor do they provide data on aircraft movements. The next phase of ILCM development is likely to include the incorporation of new modules for freight demand, aircraft movements and fleet composition.

ENDNOTES

1. Based on definitions from the Netherlands Central Bureau of Statistics.

2. See Dick Ettema, with N. Cohn and F. Savelberg, 'Monitoring the effects of the Thalys high speed train,' to be presented at PTRC, September, 1998.

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