Airport Choice in Germany - New Empirical Evidence of the German Air Traveller Survey 2003

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AIRPORT CHOICE IN GERMANY – NEW EMPIRICAL EVIDENCE OF THE GERMAN AIR TRAVELLER SURVEY 2003 –

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ABSTRACT

The paper deals with the quantitative relationship between the number of air travellers in any region and the airports chosen in Germany in 2003. The purpose of the paper is to present results of an analysis of airport choice behaviour of total air passenger demand in Germany, based on data of the German air traveller survey conducted at 17 international and 5 regional airports. About 210 000 passengers were interviewed about their trip origin, destination, choice of travel mode to the airport, purpose of their journey and further journey and person related attributes. As a result of the analysis so far, the distribution of airports chosen by all passengers coming from any region in Germany can be shown in relation to the journey purpose and destination. Based on these data, logit models have been calibrated for each market segment to forecast airport choice in relation to the accessibility and attractiveness of airports. As a further methodological step the outline of a combined neural and nested logit model of access mode and airport choice is given, which will be calibrated on the basis of the data of the German air traveller survey.

Typically, the nearest airport will be chosen by most travellers, there are, however, on average eight airports serving one region (defined as a Spatial Planning Region, of which there are 97 in Germany). If there is an international airport in a region about two thirds of the demand coming from that region will choose that airport, and about one third will choose to depart from one of seven other airports. Vice versa, each airport attracts passengers coming from almost 40 regions. There is thus an intense interaction between an airport and a large influential area.

KEYWORDS: Regional air travel demand, airport choice, air traveller survey, catchment areas of airports, travel route from origin via departing airport to destination area, logit model on airport choice, neural networks.

1. Introduction

Airport choice is at first sight a behavioural characteristic of an individual air traveller, in this paper however, we will not deal with the description of the individual choice phenomenon, but with the result of choices of all passengers of Germany in 2003. This information has been gained from passenger surveys that have been carried out at 17 international airports and 5 regional airports and that have been brought together by DLR to one overall survey in order to allow for a common evaluation of data and provide demand data related to all airports. The most valuable information in this context is the number of air journeys generated and attracted in each region of Germany and the number of passengers, coming from any of the regions, using any of the airports as point of departure or destination. Matrices have thus been calculated on the basis of the survey sample that relate the number of passengers from each Spatial Planning Region in Germany (in total 97, and 9 neighbouring countries) to each airport in Germany (in total 22 airports in Germany, with the three airports in Berlin taken as one).

It is the objective of this paper to report on the results of the survey analysis and to give some insight into the airport choice pattern of regional demand, i.e. the distribution of regional demand regarding the airports of departure or destination, and – from the perspective of the airport – the catchment areas of airports, i.e. the main portion of the passenger volume coming from a zone described by criteria like distance, access travel time, number of defined spatial units or size of area. Since the airport choice as well as the importance of the influential area varies with the characteristics of demand the information on these phenomena has been elaborated by market segment, that is by air journey distance and purpose.

The data analysed so far allow to describe not only airport choices of air travellers and catchment areas of airports in Germany, the survey data have been used also for calibrating rather plain logit models of airport choice by market segment. The objective of this is not so much of providing a tool of estimating the future airport utilisation in Germany but to learn more about the factors underlying the choice processes. It is intended to go a step further and conceive a combined neural nested logit model of access mode and airport choice. The outline of the approach is presented in this paper as an example of further research, which is being pursued by one of the authors, Marc Gelhausen.

The outline of the paper is as follows:

- Airport system of Germany
- Air passenger surveys in Germany in 2003
- Zonal concept
- Structure of air passenger demand in Germany in 2003
- Airport choice by market segment of travellers
- Catchment areas of airports by market segment
- Airport choice model by market segment
- Outlook: An advanced airport and access mode choice model – the neural nested logit model

2. Airport System of Germany

Germany, a country with a population of about 82 million people and a size of nearly 360 000 km², has a rather dense network of classified airports. There are first of all 17 international airports (see Fig. 1) which – together with some 10 regional airports – serve primarily the public air transport system with scheduled and non-scheduled services on domestic and international traffic relations. The international airports handle most of this traffic, although on some of the regional airports traffic volumes are exceeding one million passengers per year, like in Paderborn and Hahn. The latter one has been converted from a military base to a civil airport and has been chosen by Ryanair as a hub airport in Germany.

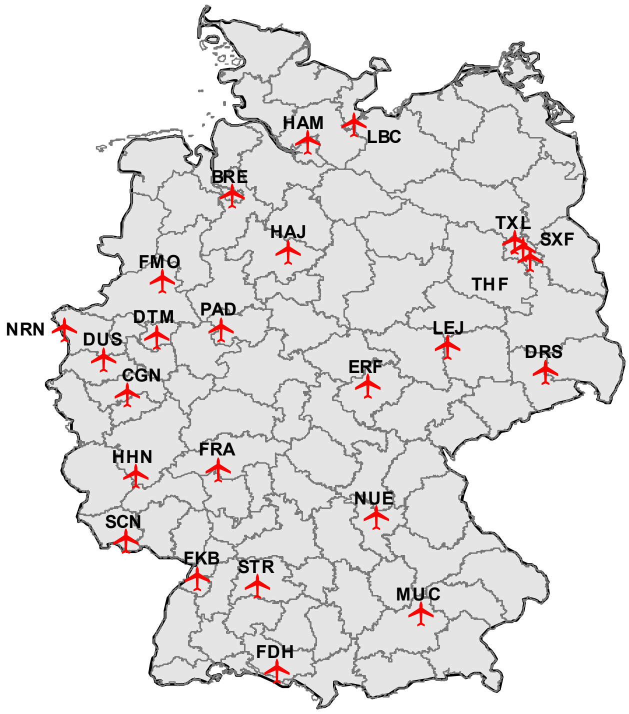

Fig. 1: Airport System of Germany (as Considered in the German Air Traveller Survey 2003)

In 2004, the international airports handled a traffic volume of almost 155 million passengers enplaned and deplaned and of about 2,2 million air transport movements (ATMs) on mainly scheduled services. Since 1992, the second year after the reunification of East and West Germany passenger traffic has grown by 78 % (4,9 % annually) and the ATM volume by 29 % (2,15% annually). Air transport has thus grown much faster than the classical car and rail mode, however, the growth has come to a halt in 2001 for three years, also influenced by the 11-September incident in New York. In 2004, the overall growth was again strong, the number of passengers grew by 8 % and the ATM volume by 3,2 %.

Germany has two hub airports, Frankfurt and München, with both origin-destination (O-D) and feeder traffic concentrations, while all the other airports handle mainly origin-destination traffic to domestic and European destinations and in addition feeder traffic to the German and to some European hub airports. The biggest airport is **Frankfurt** (FRA) with 50,8 million passengers and 477 thousand flight movements in 2004, of which 56 % belonged to the "home carrier" Lufthansa which operates its primary hub there (with a passenger share of 60 %). More than 50 % of all passengers in Frankfurt use transfer flights. The airport is located rather centrally in Germany in the Rhine-Main region, with several urban areas like Frankfurt, Darmstadt, Mainz and Wiesbaden in the neighbourhood of the airport. Altogether, there live about 4 million people in that region.

Due to growing capacity problems - Frankfurt has two parallel runways and a third runway for take-offs only, with operations dependant on each other – Lufthansa has transferred a growing part of its hub operations to **München** (MUC), with almost 27 million passengers and 383 thousand ATMs the second biggest airport in Germany. As a consequence, München airport has expanded the flight volume from 2000 to 2004 by 20 %, whereas the total volume of Germany has grown only by 2,6 % in that period. The airport serves primarily the O-D demand coming from the urban area of München, there are no other major urban areas in the southern part of Germany.

Before München became an airport with growing hub functions **Düsseldorf** (DUS) in the Rhine-Ruhr area ranked second after Frankfurt. In 2004, Düsseldorf had a traffic volume of 15,2 million passengers and about 200 thousand ATMs. A great deal of passengers in Düsseldorf is using the airport for tourism flights, primarily to Mediterranean resort areas. Düsseldorf airport is located at the Western edge of the Rhine-Ruhr District, an industrialised region with about 10 million people, predominantly living in urban areas. This catchment area is the biggest of its kind in Germany, Düsseldorf has to share it, however, with two other airports, that is Dortmund and Köln/Bonn.

In **Berlin**, 14,8 million passengers and 223 thousand flight movements were handled in 2004 by an airport system consisting of three airports, Berlin-Tegel (TXL), the main airport, Tempelhof (THF) and Schönefeld (SXF). Berlin-Tegel handles almost three quarters of total passenger traffic and two thirds of all flight movements and operates near terminal capacity. Tempelhof is an old airport, located within the urban area of Berlin, and was scheduled to be closed on environmental reasons. Because its proximity to the city centre, however, Tempelhof remains very attractive for airlines operating regional aircraft out of this airport. Schönefeld has only recently gained traffic because low cost carriers have concentrated there. The States of Berlin and Brandenburg plan a single airport for the Berlin region at the Schönefeld site, with enough capacity and lower environmental damage than Tegel and Tempelhof cause, up to the present, however, the planning has not reached an advanced stage. Like München, Berlin is a mono-nuclear city surrounded by a large rural region, the population of the Berlin region is about 3,5 million people.

Hamburg (HAM) and **Stuttgart** (STR) are two other busy airports, with almost 10 respectively 9 million passengers in 2004 not as big as the former ones. They, too, serve more or less single urban areas, with a population of almost 2 million people in Hamburg and 3 million in the Stuttgart region. Whereas Hamburg airport has a runway system consisting of two runways crossing each other and Stuttgart has to rely on a single runway, the airports **Köln/Bonn** (CGN) and **Hannover** (HAJ) have open parallel runway systems allowing for independent operations. Köln/Bonn has recently gained in importance due to low cost carrier traffic, which accounts for almost 40 % of the total traffic volume of 8,2 million passengers. The airport is located at the South-Western edge of the Rhine-Ruhr District and has with the cities of Köln and Bonn a population of more than 3 million people in the direct neighbourhood, however, lies geographically between the main airports Frankfurt (road distance: 160 kms) and Düsseldorf (distance: 67 kms). In addition, a new high speed rail line connects Köln region and the airport with Frankfurt airport and the Rhine-Main region within a riding time of about one hour.

The region of Hannover airport is characterized by the urban area of Hannover and some smaller cities further away, less than 2 million people live in the Hannover region. The airport handles with 5,2 million passengers less traffic than Köln/Bonn and operates well below the capacity limit. Similar conditions of capacity utilisation apply for **the other international and regional airports in Germany**, their traffic volumes are rather low and are well below capacity, although they generally have only one runway in operation. (An exception is Leipzig airport which has two runways, they are, however, not parallel.) These other international airports are Bremen (BRE), Dortmund (DTM), Dresden (DRS), Erfurt (ERF), Hahn (HHN), Leipzig/Halle (LEJ), Münster/Osnabrück (FMO), Nürnberg (NUE) and Saarbrücken (SCN); the selected regional airports are Friedrichshafen (FDH), Karlsruhe/Baden-Baden (FKB), Lübeck (LBC), Niederrhein-Weeze (NRN) and Paderborn (PAD). The average traffic volume of these other international airports is with 1,7 million passengers much lower than the traffic of the more important airports mentioned above, the average volume of the regional airports is even lower (763 thousand passengers).

Commercial air traffic in Germany is rather concentrated on a few airports, Frankfurt alone accounts for one third of the total passenger volume of Germany. The six airports of Frankfurt, München, Düsseldorf, of Berlin (being an airport system), Hamburg and Stuttgart with the highest traffic volumes handle more than 125 million passengers, which make up for more than 80 % of the total traffic. Only these airports have already now or face in the near future capacity problems, the other 11 international and the 5 regional airports, which carry less than 20 % of the traffic, have sufficient capacity surplus.

While most of the airports offer a mixture of scheduled, charter and tourism services and other non-scheduled services, there are several airports that are almost exclusively low cost carrier airports, that is in particular Hahn with 2,4 million, Lübeck with 0,6 million and Niederrhein with 0,8 million passengers. These traffic volumes are still relatively small, they have been generated, however, in a short period of only two to three years. As we will see later on, these airports draw their traffic from large areas, that means, that passengers of low cost carriers don't mind travelling long distances to the airport of departure in order to take advantage of cheap flights.

3. Air Passenger Surveys in Germany in 2003

Co-ordinated by the German Airports Association (ADV) and DLR each of the 22 airports mentioned carried out a passenger survey during the year 2003, in which passenger and journey information was asked for so as to reflect the demand pattern of the airport. Pre-specified samples of passengers were drawn at gates so that they could be interviewed while waiting for their flight in the departure lounge. The questions differed from airport to airport but questionnaires had a common part that covered the same questions. These referred among others to

- place of trip origin,
- place of journey origin,
- mode of access to the airport,
- journey purpose,
- duration of journey,
- route information,
- traveller information.

Information on the flight, airline and destination was gained by selecting the departure gate and organizing the sample in such a way that all flight services offered at the airport were represented in the survey. The sample size and the total number of passengers using the flight were registered, so that the sample information could be used in order to estimate the corresponding characteristics of the total demand on each link and of the airport as a whole.

Sample sizes varied with each airport depending on the total traffic volume of the airport and the specific market research interests of the airport company. They varied between over 50 thousand interviews in Düsseldorf and 1 500 in Dortmund, altogether 210 thousand passengers were questioned at 22 airports during most of the time in 2003. The corresponding volume of total demand, that is the number of passengers departing at all airports and commencing their trip there (thus excluding corresponding passengers) was 55,8 million enplaning passengers, a figure, which has been derived from the official air traffic statistics of Germany for the year 2003, issued by the Federal Statistical Office (Statistisches Bundesamt 2004). This gives an overall sampling factor of one in 266, the actual sampling factors were, however, specified for each flight separately.

By means of the co-ordination process it was guaranteed that the same contents of information (see list above) was gained and that this information was coded in the same way at all airports. Only on this basis it was possible to merge all airport specific samples to one overall sample, which allowed to retrieve information regarding the total demand in Germany, and not only information regarding the demand using the airport of departure. By bringing together all airport samples it was possible to gain information on the air trip generation in all regions of Germany including routing characteristics like access modes and airports used by passengers for departing for their trip.

In Fig. 2 we have put together some quantitative details of zones of trip origin, passengers and trips, and of zones of destination as represented in the data set of the German-wide survey. The original information on the trip origin has been elaborated so that trip origins will be assigned to specified zones, which are defined as "Spatial Planning Regions" in Germany and the neighbouring States of Germany (see also Chapter 4: Zonal Concept). Destination data - originally stated as airport of destination – were maintained as such in case that the destination was a domestic airport, or assigned to regions representing parts of countries, like in the UK London and the other parts of the UK, to countries, like Switzerland, or to greater regions like South-America. Trip data include in addition the airport of departure, transfer airport, purpose, duration, access mode, and some traveller statistics like age and gender. With the flight specific scaling factors data become available on the trip chain from the origin via departing airport to the airport and the region of destination of all passengers of Germany.

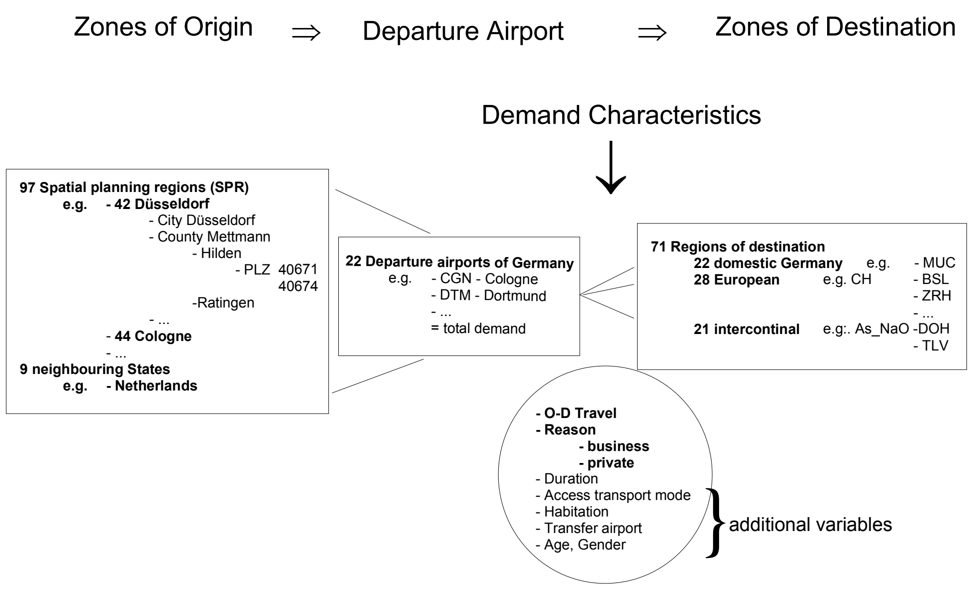

Fig. 2: Analysis of the Air Passenger Survey 2003

4. Zonal Concept

As already mentioned above trip origins and destinations have been assigned to zones in Germany which represent Spatial Planning Regions. They are used in regional, spatial and transport planning by corresponding planning authorities like the Federal Ministry of Housing and Transport of Germany. Fig. 3 shows the subdivision of Germany into altogether 97 Spatial Planning Regions (SPR's); shown are as well the location of airports and the population living in the SPR's. In order to visualize the zonal size in terms of the population 7 size categories have been defined, ranging from smaller than 250 thousand to 3 - 4 million people per region.

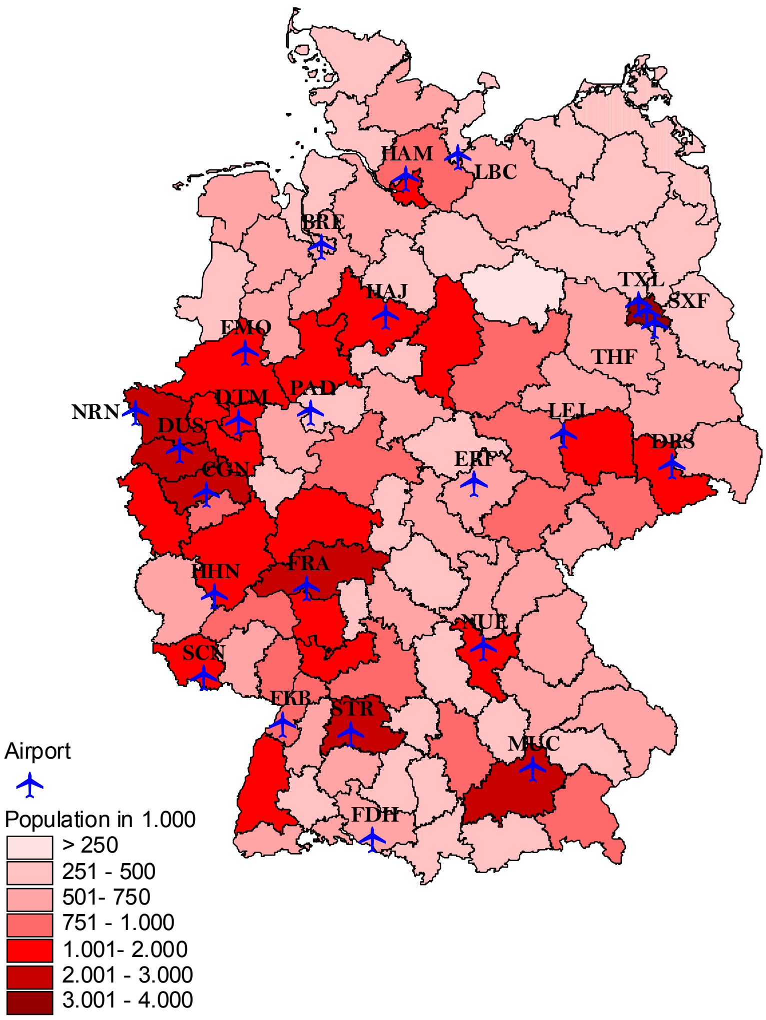

Fig. 3: Population in Spatial Planning Regions of Germany

As can be seen population in Germany is to some degree concentrated along a few corridors, the most important one from Düsseldorf to Rhine-Main, Stuttgart and to München, another one from the Rhine-Ruhr District to Hannover and Berlin and to Dresden. Out of the total population of 82,5 million in Germany around 10 million people are living in the Rhine-Ruhr District, and in the State of North-Rhine - Westphalia 18 million people.

The average size of a SPR is 850 thousand inhabitants, with a range of almost 240 thousand people in the SPR "Altmark" East of Berlin, being the smallest zone, to 3,4 million people in Berlin, being the biggest zone. As can be seen the main airports are lying in SPR's with high populations. In the following we give for each of the 17 international airports the population of the SPR in which the airport is located, and in addition the number of passengers enplaned and deplaned in the year 2004 (Source: ADV 2005):

Airport	Population of Airport Zone (SPR) (Thousands)	Passengers (2004) (Thousands)
Hamburg	1 727	9 818
Bremen	542	1 650
Hannover	1 417	5 173
Berlin	3 390	14 781
Münster/Osnabrück	1 571	1 457
Dortmund	1 205	1 179
Düsseldorf	2 979	15 150
Köln/Bonn	2 156	8 275
Frankfurt	2 710	50 768
Erfurt	702	526
Leipzig/Halle	1 083	1 950
Dresden	1 019	1 577
Hahn	1 277	2 745
Saarbrücken	1 065	412
Stuttgart	2 642	8 700
Nürnberg	1 282	3 592
München	2 493	26 666
Total	29 260	154 419

The 5 selected regional airports, which handle a traffic volume of 3,8 million passengers, are typically located in zones with less people than the zones with international airports, with the exception of Niederrhein-Weeze airport, the SPR of which has 2,3 million people. On the other hand, Bremen and Erfurt are two international airports located in rather small zones, with populations of 542 respectively 702 thousand people. On average, an airport zone has a population of 1,7 million inhabitants, that is twice the size of the average SPR. Altogether there live 29,3 million people in the direct neighbourhood of the 17 international airports, which accounts for 35 % of the total population.

5. Structure of Air Passenger Demand in Germany in 2003

Before dealing with airport choice and catchment areas it is useful to describe the structure of demand for air services in Germany in terms of market segments related to zone of origin, destination and travel purpose.

If we take as a unit of demand the air journey, meaning the ensemble of trips from the origin to the destination(s) and retour, then the total demand in 2003 was 48,6 million air journeys (corresponding to 55,8 million enplaning passengers and 154,4 million enplaning and deplaning passengers incl. transfer passengers), of which 7,2 million were domestic (15 %) and 41,5 million border-crossing journeys (85 %). 78 % of the border-crossing travel had European and correspondingly 22 % intercontinental destinations. The biggest segment with two thirds of the total is thus the travel volume to European destinations, which constitutes a rather heterogeneous market made up by intensive tourism to Mediterranean resorts and business travel to mainly neighbouring countries of Germany, the UK and Scandinavian countries.

Looking into the travel purpose structure we find that in domestic air travel this mode is chosen primarily for business travel reasons (69 %), in European and intercontinental travel only in 28 % of all trips, the majority travels long distance for private, mainly holiday purposes. Short stay personal trips account only for 10 % of all private border-crossing trips, 90 % are holiday journeys. Whereas international business travel is more evenly subdivided into travel made by Germans and by visitors, Germans constitute the majority of holiday travellers to international destinations, 9 out of 10 travellers in holiday tourism are Germans flying to resorts in Europe and to intercontinental destinations.

Short private trips are not yet a big market segment in air travel (about 10 %), they are, however, the main market of low cost carriers. These airlines operate in Germany only since a few years, but have been very successful in generating new demand and attracting travellers from traditional network carriers to their no-frills services, mainly in the European market. In the pre-low-cost-carrier times, the segment of short private journeys was therefore much lower, only about 4 %.

The regional demand distribution in Germany – one of the main results of the traveller survey analysis - is shown in Fig. 4. The regional demand is given for each SPR according to 8 volume classes. The concentration of demand generation in the airport zones is clearly demonstrated. Low demand regions are rural zones, particularly in the East-German States. The airports with the highest traffic volumes are located in zones which are characterised by high demand levels, both in terms of the absolute number of travellers and the propensity to fly (journeys per person), in particular the regions of Hamburg, Berlin, Düsseldorf, Köln, Frankfurt, Stuttgart and München. This does not mean, however, that airports attract only those travellers, who come from the zones directly neighbouring the airports, as we will see in the next chapter.

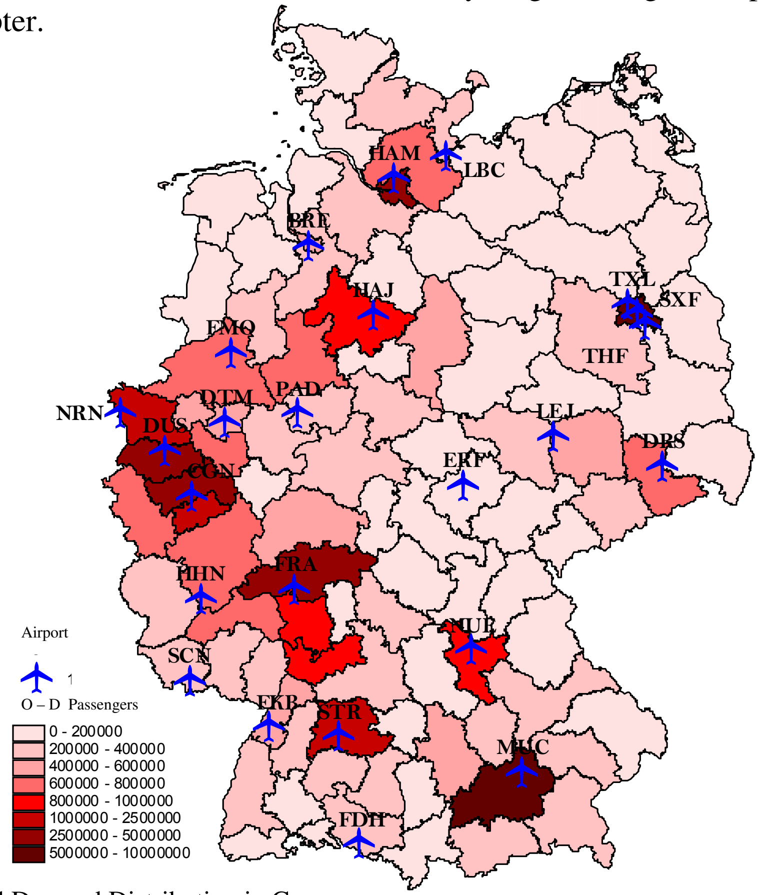

Fig. 4: Regional Demand Distribution in Germany

6. Airport Choice by Market Segment of Travellers

As already mentioned we will not deal with the individual choice process here, the emphasis is rather on the description of the overall revealed result of airport choices of all passengers of Germany. Based on the combined data of the air traveller survey at all airports in Germany and the official air traffic statistics we have information on the route of travellers from their origin – as represented by the Spatial Planning Region -, via the airport of departure to the destination airport and region – as represented by a region within a country or a country or, in case of intercontinental destinations, an ensemble of countries.

As the choice of the airport depends on factors which include preferences of the traveller, the journey purpose and destination, the time to get to the airport and the quality and attractiveness of the airport including the frequency and network coverage of flights offered from the airport, one should describe airport choice by market segment. For the purposes of describing the situation in Germany in this paper and not overloading the description with detail we have concentrated the data analysis on the following market segments:

- Travellers to domestic destinations, which are to great deal business travellers
- Travellers with journey origin in Germany to European destinations, travelling for business purposes
- Travellers with journey origin in Germany to European destinations, travelling for holiday purposes
- Travellers with journey origin in Germany to European destinations, travelling for short stay personal reasons
- Travellers with journey origin in Germany to intercontinental destinations, travelling for business purposes
- Travellers with journey origin in Germany to intercontinental destinations, travelling for private reasons, which are mainly holiday travel.

In the border-crossing segments we concentrate on travellers with journey origin in Germany because airport choice depends on the fact whether or not one begins the journey or the trip back home. As we have seen in the description of the demand structure of air travel to and from Germany there are many more travellers originating their journey in Germany (mainly Germans) than outside the country (mainly visitors to Germany).

To give an overview of an “average” airport choice behaviour we will first give some information on the distribution of airports selected by all travellers. On the basis of the regional structure given by the Spatial Planning Regions we have found that on average air travellers of any region in Germany choose between eight airports, with a standard deviation of 2 airports. For the analysis we have excluded those SPR’s from where less than 500 passengers (corresponding to 2-3 observed passengers in the sample) came to the airport. Interestingly, the demand of the SPR Düsseldorf, in which Düsseldorf airport of is located, and which is with 3,1 million air travellers one of the regions in Germany with a very high traffic volume, this demand is using 14 airports for commencing a flight; no other region in Germany is served by so many airports. Naturally, the demand of the Düsseldorf region is concentrated on the Düsseldorf airport, 86 % of the trips generated and attracted by the zone use Düsseldorf airport, but the other 14 % are selecting 13 other airports. On the other hand, the minimum number of airports used by the demand of one region – and thus the highest concentration of selecting airports in the revealed choice behaviour - is 3 airports. There is not a single zone the demand of which is served by just one airport. We can conclude that although there is a concentration of demand in selecting the nearest or most attractive airport -

in fact, 67 % of the demand of an airport region chooses this airport -, in a decentralised airport environment like in Germany air travellers of a given region are selecting between a great number of airports - actually eight - for departing for an air journey.

In order to illustrate the relative airport use of regional demand we have selected two examples, the demand distribution of an industrialised zone without an airport, that is Bielefeld, and of an urban zone with airport, Köln. The number of trips generated and attracted in the zone of Bielefeld was in 2003 almost 700 thousand and thus higher than the average regional demand, which was 575 thousand passengers. These travellers have chosen 12 airports for departing, as can be seen in Fig. 5. Most of them have started their air trip at Hannover airport, although two airports, Münster/Osnabrück and Paderborn, are lying closer to Bielefeld, they lack, however, network density and flight frequency as compared with Hannover. Paderborn is the nearest airport, because of a relative lack in attractiveness this airport ranked only second. Frankfurt, the most important airport in Germany, attracted only about 10 % of the Bielefeld demand, Düsseldorf airport attracted even more passengers. The distance Bielefeld – Frankfurt is, however, with 320 km greater than the distance to Düsseldorf with 175 km.

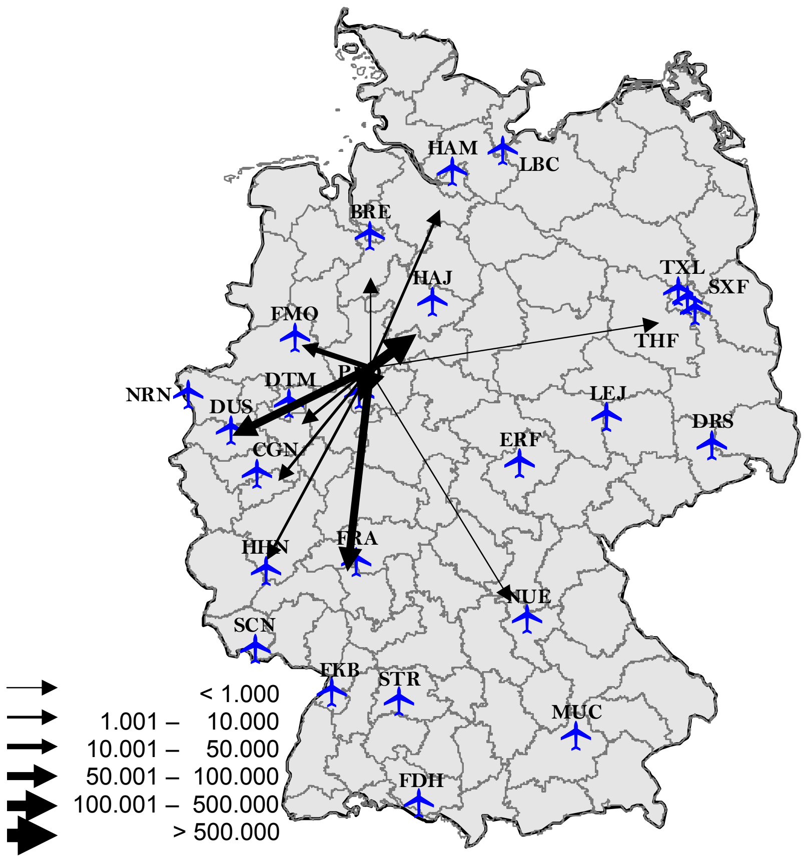

Fig. 5: Demand Distribution of the SPR Bielefeld

In Fig. 6, the demand distribution of the SPR Köln is shown. This region has a population of 2,2 million inhabitants and a trip generation of 2,6 million air travellers. The region is as such one of the most important demand regions of Germany and has an airport with a wide offer of flights, however, no intercontinental services. Because of the relative proximity of the Frankfurt and Düsseldorf airports with many more flights and destinations to offer, Köln airport attracts less than 70 % of the SPR Köln, almost 30 % of the demand use Düsseldorf and Frankfurt and to a small degree 6 other airports, among them Hahn, an airport more than 160 km away with low cost carrier flights only. The competition among airports – or more precisely among airlines at these airports – for the demand in the Köln region is thus very strong.

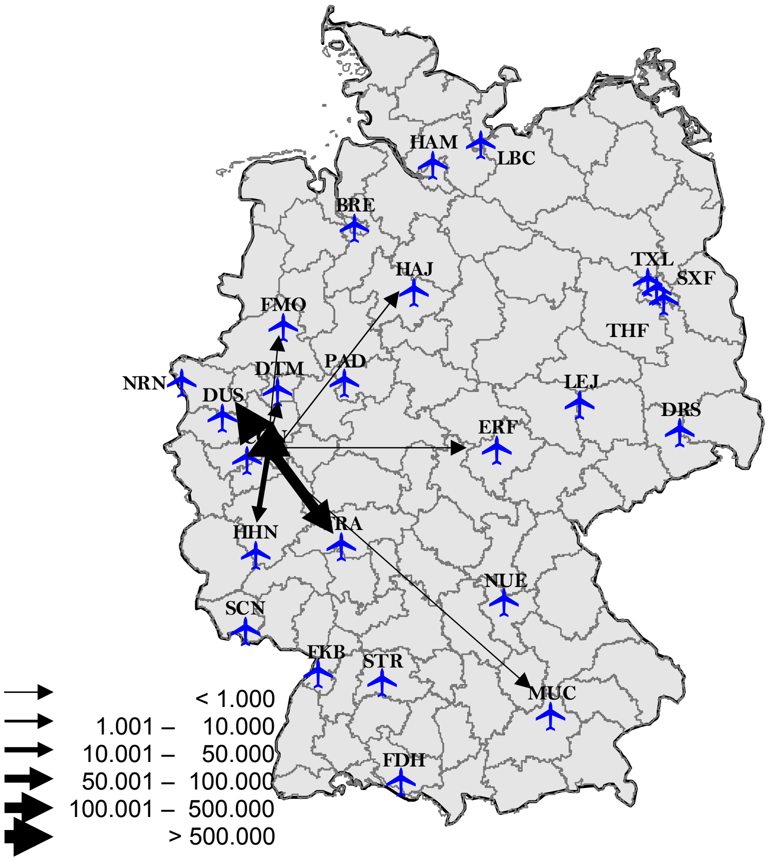

Fig: 6: Demand Distribution of the SPR Köln

- Domestic Demand

Air travel in the domestic network of Germany is short distance air travel and as such competing with ground modes. O-D passengers are in most cases business travellers and therefore time sensitive. One would assume that they use the plane only if the access to the airport and to the flight is rather short. Indeed, the demand is much more concentrated around airports than border crossing travel, and the demand of any region uses on average only 3 airports for beginning an air trip, with a standard deviation of 1. There is a great number of SPR's the demand of which uses just one airport, on the other side, the Düsseldorf zone is served by as many as 8 airports.

- European Business Travel Demand of Germans

Like in the domestic case we would assume that business travellers because of their high time value choose the nearest airport for beginning a trip by air. If the total demand of any given region in Germany is served on average by 8 airports, business travel demand to European destinations is served by just 3 airports on average (standard deviation of 2), as is the case for domestic travel. In almost one third of all regions the demand has chosen one or two airports, and there is only one region with 10 airports serving travellers coming from this SPR, that is the Bielefeld region.

- European Holiday Travel Demand of Germans

The single most important market segment of the total demand of Germany is the holiday travel to European destinations, 38 % of all journeys belong to this group. Holiday travellers are price sensitive and thus prepared to travel further distances to airports of departure in their search for low-priced holiday packages or for just air tickets. As we see from the survey analysis the demand of any spatial planning region in Germany has realised a choice behaviour of selecting 7 airports for holiday trip departures, with a standard deviation of 2. This average value varies between 2 airports in a few cases and 12 airports chosen by travellers coming from the Göttingen zone.

There is of course a strong concentration of the demand coming from airport regions on using the airport of these zones, ranging up to 97 % in the Berlin zone and even 98 % in the München zone. Depending however on the quality and density of tourism flights the regional demand chooses other airports with a better offer as well. An example is the Münster zone where only 40 % use the own airport for holiday departures, but more than on third use Düsseldorf as airport of departure. Düsseldorf is the airport in Germany with the densest tourism flight schedule.

- European Short Stay Personal Travel Demand of Germans

Private journeys with less than 5 days away have constituted only a small fraction of total demand, but have grown strongly recently with the upcoming of low cost carrier services at some airports in Germany, especially in Hahn, Köln/Bonn, München et al. Since low cost carriers have concentrated their flights so far on a few airports in 2003, airport choice by regional demand was affected by this limitation. Only 3 airports have been chosen by the demand of an average zone in Germany (standard deviation of 2). The number of airports chosen varied between one airport in some regions and 7 airports in the demand of 3 SPR’s, among them Bielefeld.

The region with the highest demand for short private trips to European destinations is the Rhine-Main SPR, with Frankfurt as the main generator, to be followed by the Köln region. Interestingly, Frankfurt airport does not offer low cost carrier services as is the case at Köln/Bonn or Hahn and other airports. The demand of the Frankfurt region is therefore oriented to other airports as well, in fact 6 airports are serving this region, and more than one quarter of the demand uses Hahn airport for departures.

- Intercontinental Business Travel Demand of Germans

For describing airport choice in intercontinental travel we have not excluded the demand of less than 500 travellers coming from a region, because of the small demand in these segments. Otherwise, too many zones would not be counted; in fact, there would be zones without any airport connected to the demand from that region, which is not realistic.

In intercontinental travel, services of direct flights are concentrated on a few airports, in particular on Frankfurt and München. Business travellers often use the car or high speed rail in order to reach the airport, either for a feeder flight to the airport of the intercontinental flight, or directly for the intercontinental flight. Only 3 airports are chosen by travellers from a region on average (standard deviation of 1), indicating that a great number of travellers come directly to the airport offering intercontinental flights.

- Intercontinental Private Travel Demand of Germans

Private trips in intercontinental travel have not been further subdivided, since over 98 % are holiday trips, short stay personal trips do not play a significant role there. As with business travel, holiday travellers have only a limited choice of airports offering direct intercontinental flights, from most airports travellers have first to take a feeder flight, or they use a ground mode from their region of trip origin to the airport with intercontinental flights.

The survey results show that the demand of a SPR in Germany chooses to depart at one out of 6 airports on average (standard deviation of 2), with a maximum of 10 airports of just one region and a minimum of 2 airports chosen by the travellers from a few regions. Most of the holiday travellers with intercontinental destinations come from the München region, who have chosen in 92 % of all journeys München airport, 8 % of travellers have chosen an airport out of 5 other ones.

7. Catchment Areas of Airports by Market Segment

So far we have taken the view from the region to the airport, now we will take the standpoint of the airport operator and look into the regional distribution of traffic volume of the airport under consideration. So far the demand volume of the region and its distribution was considered, now it is the airport traffic volume and its spatial distribution. This information is relevant for market research purposes of the airport, whereas the former view is taken by airport choice modelers of demand.

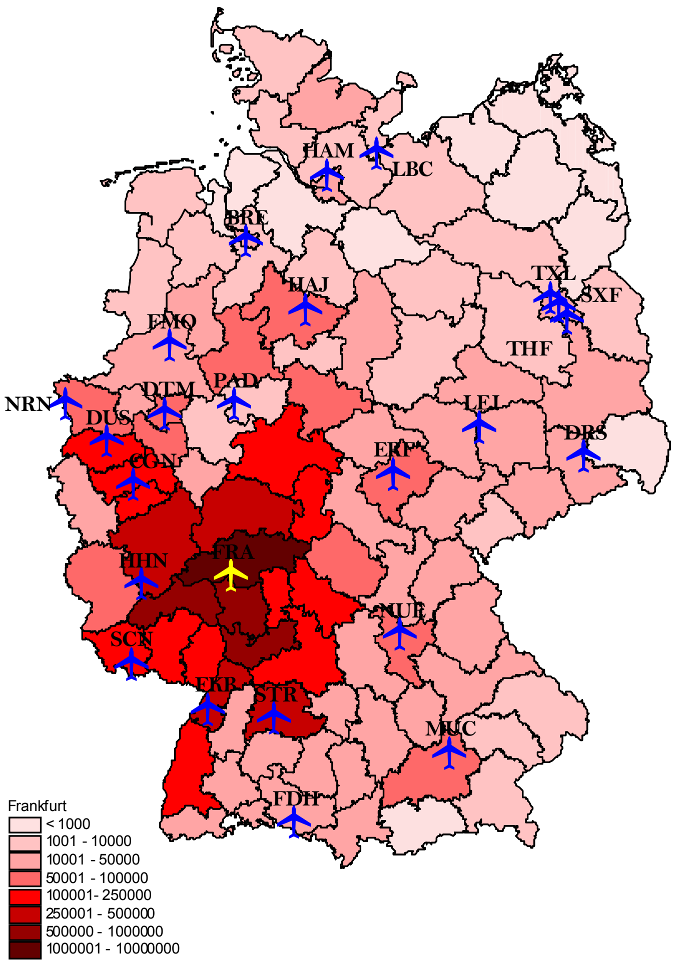

Fig. 7: Catchment Area of Frankfurt Airport

Before looking into the market segment specific distribution of airport traffic let us shortly describe the catchment areas of total airport traffic. If we count the SPR's from which airports in Germany draw passengers and exclude those regions which contribute less than 5oo (estimated) passengers then each airport attracts traffic from 39 regions in Germany on average, with a standard deviation of 28 regions. The average catchment area of an airport comprises thus a zone which includes 40 % of all regions of Germany, however, as indicated by the high value of standard deviation, there is a high variance in the size of catchment areas. The international airport with the smallest number of SPR'S is the airport of Dresden with a traffic volume of 1,6 million passengers, who come from only 11 regions. In contrast the catchment area of the biggest airport of Germany, Frankfurt, is almost the whole of the country, that are 89 SPR's (see Fig. 7).

Another way of describing catchment areas of airports is defining a certain area around an airport and determining the demand of that region that is served by the airport. For the purpose of this paper we have taken a radius varying between 25, 50 and 75 kms around each airport and counted the passengers within each radius who have selected the airport in the centre of that zone. We have found out that airports attract on average 31 % of their traffic volume from an area with a radius of 25 kms, 56 % from an area with a radius of 50 kms and 72 % of their traffic volume from an area with a radius of 75 kms around the airport. In Fig. 8 we show the percentages of traffic volume attracted by each airport coming from a region with a radius of 50 kms around the airport. The average percentage of 56 % varies strongly between airports, Berlin attracts 85 % of the passengers from such a region, whereas Frankfurt only 37 %.

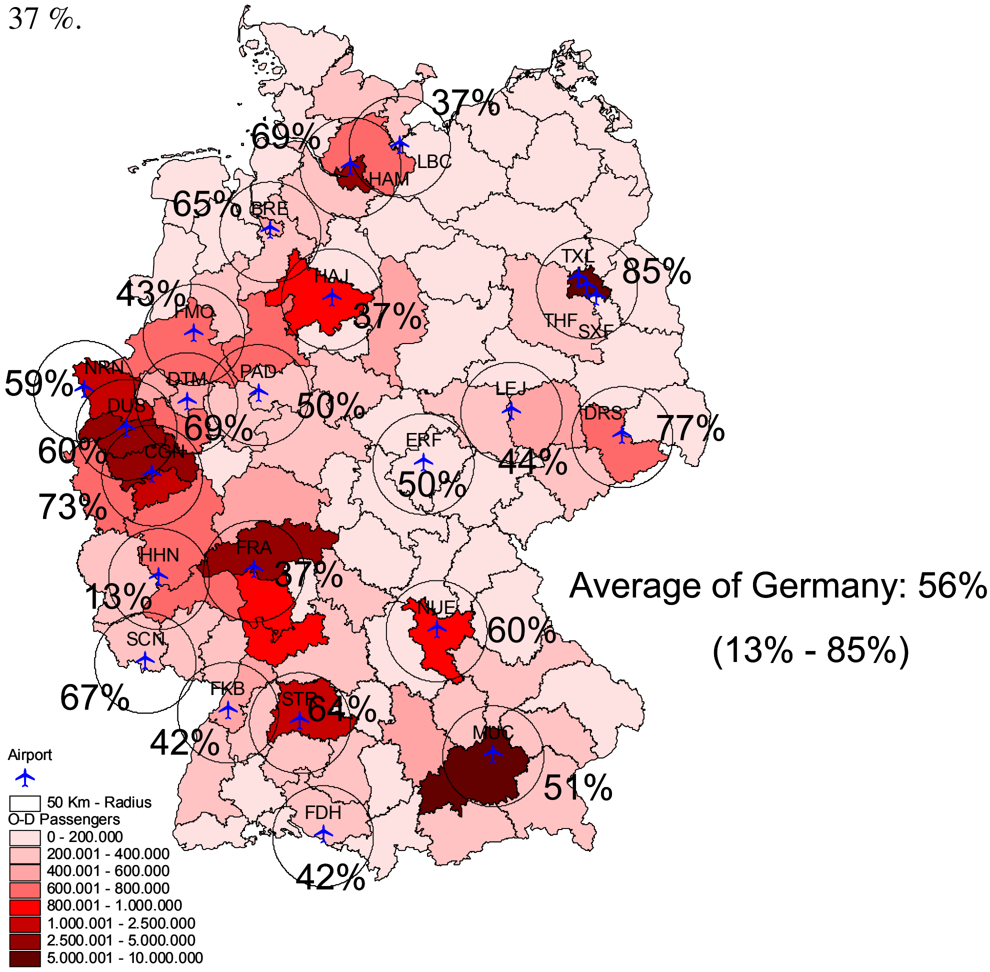

Fig. 8: Catchment Areas of Airports in Germany – Portion of Traffic Coming from a Zone within a Radius of 50 kms around the Airport –

A special case is the low cost carrier airport Hahn which attracts passengers coming from 76 SPR’s in Germany and only 13 % of its traffic volume out of a zone within a radius of 50 kms. This can be explained by the fact, that the nearest urban areas of Hahn airport are more than 120 kms away from that airport. Nevertheless, from the size of the catchment area of Hahn airport it can be concluded, too, that passengers of low cost services do not mind going long ways in order to take advantage of low priced services.

- Domestic Demand

Clearly, short distance travel by air in the domestic network is interesting primarily for those living near airports, since otherwise the time advantage in relation to slower ground modes will disappear. On average, airports attract passengers for domestic services coming from 13 SPR’s, with a standard deviation of 11. This average has to be seen against the fact that some of the airports have domestic flights only to a small number of destinations. Frankfurt airport with 1,6 million passengers to domestic destinations draws these passengers from an area comprising 42 SPR’s, whereas the domestic demand of Dresden airport comes from 7 regions only.

- European Business Travel Demand of Germans

Distances to business destinations in Europe vary strongly, modal competition, however, is rather limited, since business travellers have a high time value. The average catchment area of this market segment includes 18 SPR’s, with a high value of standard deviation of 16. While the biggest airport, Frankfurt, attracts passengers from almost 60 regions, passengers of the much smaller airport Bremen come from just 8 SPR’s.

Hahn airport is again an interesting, but special case; Hahn offers almost exclusively low cost services to European destinations, which are frequented by business travellers as well. Hahn attracts business travellers from 36 SPR’s, no other airport except Frankfurt has such a great catchment area, indicating that there are price sensitive business travellers, too, who are prepared to pay more time to reach an airport from which they can fly to their destination by means of low priced services.

- European Holiday Travel Demand of Germans

As we have seen already, this market segment is the most important one in terms of passengers. Traditional network carriers, charter and low cost carriers compete for this market which consisted in 2003 of more than 18 million passengers. The airport with the highest travel volume in this segment is since long time Düsseldorf, which handled in 2003 almost 3 million passengers. While Düsseldorf attracted passengers from as many as almost 60 regions in Germany, the average number of all airports was 32, with a standard deviation 23 zones. Smaller airports like Dresden, Friedrichshafen, or Saarbrücken drew passengers from areas comprised of about 10 SPR’s, whereas bigger airports like Köln/Bonn, Hannover, and München had more than 50 contributing regions. Frankfurt, the second biggest airport in this market segment, had more than 80 demand generating zones, but also Hahn airport had with almost 70 regions more than all other airports except Frankfurt.

- European Short Stay Personal Travel Demand of Germans

The demand for short duration private trips to European destinations is still much smaller than the holiday market, the difference is in the order of the factor 10. Because of the rapid progress of low cost carriers this market segment is growing fast. Never the less, airports drew the traffic on average from 13 regions in Germany, with a standard deviation of as many as 12 regions. Hahn airport is here the airport with the greatest influential area with about 40 regions, while Köln/Bonn and Frankfurt, the two other important airports for this market segment attract passengers from about 30 regions.

- Intercontinental Business Travel Demand of Germans

This market segment is with 3 % of the total demand the smallest group among the selected segments. As has been said already, intercontinental direct services have been offered in 2003 only from Frankfurt and München. Business travellers to intercontinental destinations have the choice between departing at the nearest airport for a feeder flight and going first by means of car or rail to an airport with direct intercontinental flights. As we can see from the survey there are on average 8 regions serving an airport, but this figure is not very indicative since only Frankfurt has a catchment area of over 55 SPR's, while all other airports have relatively small catchment areas. Even München airport has an influential area of only 18 regions, and some smaller airports don't attract any business passenger for intercontinental destinations, like Erfurt, Hahn and Saarbrücken.

- Intercontinental Private Travel Demand of Germans

This market segment is more than three times bigger than the business travel group to intercontinental destinations and consists practically only of holiday travellers. They are thus price sensitive and are looking for low priced flights, not minding going long ways to airports that offer these flights. As in the former group, airports draw passengers from areas which vary greatly. Frankfurt, the main hub airport of Germany, attracts almost half of all passengers of this group, coming from over 80 regions. München as the second hub airport attracts passengers from about 50 regions, while all other airports have much smaller catchment areas. There are again some regional airports without any passenger to intercontinental destinations, like Hahn and Lübeck.

As we have seen in the domestic market segment already, where some airports have only a few established service connections with other airports, catchment areas may be regarded as a sensible concept only, where airports have flights both to a sufficient number of destinations and of sufficient frequencies. If airports offer only feeder flights to hub airports then their catchment areas can be very small and depend on the number of flight connections with hub airports.

8. Airport Choice Model by Market Segment

- Introduction

So far we have described the main characteristics of revealed airport choice by air travellers of Germany. The empirical basis was the survey of air passengers at German airports in 2003, which has been scaled up to represent the total air demand of Germany. Now we use the survey sample in order to calibrate a logit model of airport choice.

As mentioned in the introductory chapter the purpose of the modeling effort is not so much to provide a tool for forecasting airport choice in real world situations but to present a learning step towards a more sophisticated airport and access choice model as outlined in the next chapter. This approach tries to identify the main factors determining airport choice. For this purpose the same market segments are retained as in the former analysis. They are:

- Domestic air demand
- European short stay personal travel demand generated in Germany
- European business travel demand generated in Germany
- Intercontinental private travel demand generated in Germany
- Intercontinental business travel demand generated in Germany

So far, we have not succeeded in calibrating a model of airport choice of European holiday travel demand within the underlying framework of variables and model specification. We assume that the influential factors that have been specified so far, such as access time and existence or non-existence of direct services are not significant in this market segment, they have been regarded as insufficient in due course of the statistical analysis. In addition, the plain logit model may be insufficient for representing the phenomenon of airport choice. The re-estimation will be a topic of a more advanced model with more variables.

- Model Estimation

To estimate an airport choice model within the logit framework it is assumed that the valuation of an airport by an air passenger is independent from his valuation of other airports (Independence of Irrelevant Alternatives, IIA property, see for example Maier and Weiss 1990). To model correlations between airports a nested logit approach for example has to be used. Furthermore access mode choice is not considered and thus travel time to the airport is approximated by travel time with a car.

The probability of choosing an alternative i out of the choice set j by person n can be estimated by calibrating a logit model such as (see Train 2003):

$$P_{i,n} = \frac{e^{U_{i,n}}}{\sum_j e^{U_{j,n}}}$$

On a higher aggregation level the computed probabilities can be interpreted as market shares. $\mathbf{U_{i,n}}$ represents the utility function and assigns to each alternative a value (the utility) depending on the preferences of the person or group considered. The utility is a measure of goodness of the alternative. Usually every homogenous group of persons has a different utility function which represents the preferences of this particular group. In principal the utility function can take an arbitrary functional form, but for reasons of simplicity usually a linear-in-parameters utility function is chosen:

$$U_{i,n} = a_{i,n} + \sum_k b_{k,n} * x_{k,i,n}$$

It is composed of an alternative-specific constant term $\mathbf{a_{i,n}}$ for all but one alternatives and k variables $\mathbf{x_{k,i,n}}$ describing the alternatives and being relevant for the choice. $\mathbf{b_{k,n}}$ are the related coefficients to estimate. One alternative-specific constant has to be set to zero to make the model to be identifiable, in this case airport Stuttgart (STR) was chosen. A linear-additiv utility function assumes a constant trade-off between the attributes.

The model is estimated by means of the maximum likelihood method. Significant parameters are identified with the t-test and the R^2 as a measure of goodness of fit of the model. This R^2 has a different meaning than the R^2 in least squares estimation procedures. Here R^2 is defined as

$$R^2 = 1 - {LogL_{mod}}/{LogL_{const}}$$

where $\mathbf{LogL_{mod}}$ is the Log-Likelihood of the unrestricted model and $\mathbf{LogL_{const}}$ is the Log-Likelihood of a model with just a set of alternative-specific constants. It is a measure of the explaining power of variables.

The sample was not randomly chosen and individuals with the same attributes were grouped together, so that weights had to be used for estimation. The number of observations stated in the tables below does not account for this, the number is in fact higher. Attributes, which possibly might influence airport choice are (in brackets are the variable names as used in the functions and as shown in the tables below):

- Travel time to the airport, measured as car driving time (Time)
- Whether there is a direct flight connection to the destination or not (Direct, binary variable)
- The number of destinations in a region with a direct flight connection (NDest), in this case domestic, Europe and intercontinental, of an airport
- The flight frequency to a region measured as flights per week, in this case domestic, Europe and intercontinental, of an airport
- The number of air passengers departing from an airport per year as a measure of the destination quality of an airport

Not all variables showed sufficient significance levels, partly depending on the market segment.

- Estimation Results

Tables 1 to 5 present the final estimation results of the five market segments mentioned above. The abbreviated airport names (IATA code) are the appropriate alternative-specific constants. The variable NDest refers to the number of destinations within the adequate region, for example in the model for domestic air traffic NDest is the number of destinations in Germany.

Variable	Coefficient	Standard Error	t-ratio	p-value
Time	-0,06681788	0,447531D-04	-1493,034	0,0000
Direct	3,51150449	0,00855271	410,572	0,0000
BER	-0,55376090	0,01556074	-35,587	0,0000
BRE	-1,43156627	0,01300579	-110,071	0,0000
CGN	0,99847416	0,00784112	127,338	0,0000
DRS	-3,16248987	0,01715656	-184,331	0,0000
DTM	-1,33788390	0,00940263	-142,288	0,0000
DUS	0,80472909	0,00798787	100,744	0,0000
ERF	-4,42925460	0,02550578	-173,657	0,0000
FDH	-4,24128624	0,01290878	-328,558	0,0000
FKB	-2,21030618	0,02550801	-86,651	0,0000
FMO	-0,97425933	0,00968466	-100,598	0,0000
FRA	0,75601080	0,00599516	126,104	0,0000
HAJ	-1,07034852	0,01273806	-84,028	0,0000
HAM	-1,35410712	0,01438881	-94,108	0,0000
HHN	-1,00735306	0,02680430	-37,582	0,0000
LEJ	-3,60634308	0,01661341	-217,074	0,0000
MUC	1,28418563	0,00583851	219,951	0,0000
NRN	1,71651876	0,01605062	106,944	0,0000
NUE	-1,20423169	0,00797970	-150,912	0,0000
PAD	-1,04133662	0,01142777	-91,123	0,0000
SCN	-3,14741654	0,01391184	-226,240	0,0000

R2 = 0,88348

No. obs. = 9045

Tab. 1: Logit Model Estimation Results of Airport Choice of the Domestic Demand Market Segment

Variable	Coefficient	Standard Error	t-ratio	p-value
Time	-0,04289179	0,402070D-04	-1066,774	0,0000
Direct	3,88044749	0,00529611	732,698	0,0000
BER	-0,71820169	0,01499498	-47,896	0,0000
BRE	-0,90026246	0,01575832	-57,129	0,0000
CGN	1,56986028	0,00840650	186,744	0,0000
DRS	-2,86731286	0,02690938	-106,554	0,0000
DTM	0,37884478	0,00966397	39,202	0,0000
DUS	0,76247039	0,00870862	87,554	0,0000
ERF	-2,19771659	0,03526169	-62,326	0,0000
FDH	0,06762492	0,01778388	3,803	0,0001
FKB	-0,91920380	0,01769255	-51,954	0,0000
FMO	0,44120075	0,01083778	40,710	0,0000
FRA	1,15530032	0,00754227	153,177	0,0000
HAJ	-0,35130452	0,01079775	-32,535	0,0000
HAM	-0,11424800	0,01349936	-8,463	0,0000
HHN	3,97023413	0,00910390	436,103	0,0000
LEJ	-3,44517597	0,02737226	-125,864	0,0000
MUC	0,43788865	0,00945804	46,298	0,0000
NRN	1,20188529	0,01164162	103,240	0,0000
NUE	0,04498114	0,01080883	4,162	0,0000
PAD	-2,89210689	0,03947797	-73,259	0,0000
SCN	0,28996895	0,02061737	14,064	0,0000

R2 = 0,74321

No. obs. = 4498

Tab. 2: Logit Model Estimation Results of Airport Choice of the European Short Stay Personal Travel Market Segment

Variable	Coefficient	Standard Error	t-ratio	p-value
Time	-0,04454382	0,272443D-04	-1634,978	0,0000
Direct	2,55978962	0,00280431	912,806	0,0000
NDest	0,02612855	0,00083567	31,267	0,0000
BER	-0,29580339	0,01231015	-24,029	0,0000
BRE	0,71209040	0,04343498	16,394	0,0000
CGN	0,28677339	0,01047010	27,39	0,0000
DRS	-0,17117489	0,04570551	-3,745	0,0002
DTM	0,38834451	0,04482988	8,663	0,0000
DUS	-0,40891396	0,03203942	-12,763	0,0000
ERF	-1,98862888	0,05272587	-37,716	0,0000
FDH	-0,44724106	0,05431275	-8,235	0,0000
FKB	-1,24702656	0,05378870	-23,184	0,0000
FMO	0,66493107	0,04088002	16,265	0,0000
FRA	-0,59518166	0,07274796	-8,181	0,0000
HAJ	-0,33562635	0,00742128	-45,225	0,0000
HAM	-0,08945093	0,00801638	-11,159	0,0000
HHN	3,75942983	0,04803026	78,272	0,0000
LEJ	-1,14865579	0,03610768	-31,812	0,0000
MUC	-0,60131888	0,04542528	-13,238	0,0000
NRN	1,47205429	0,06102061	24,124	0,0000
NUE	0,39938172	0,03213663	12,428	0,0000
PAD	0,21966330	0,04275751	5,137	0,0000
SCN	-0,44478600	0,05249479	-8,473	0,0000

R2 = 0,85309

No. obs. = 11923

Tab. 3: Logit Model Estimation Results of Airport Choice of the European Business Travel Market Segment

Variable	Coefficient	Standard Error	t-ratio	p-value
Time	-0,02766986	0,151791D-04	-1822,892	0,0000
Direct	0,87921459	0,00216316	406,450	0,0000
NDest	0,02147986	0,00065713	32,687	0,0000
BER	-1,10455764	0,00721016	-153,195	0,0000
BRE	-1,48059835	0,00677783	-218,447	0,0000
CGN	-1,44920317	0,00526186	-275,416	0,0000
DRS	-2,05754087	0,00675534	-304,580	0,0000
DTM	-3,38522610	0,01237662	-273,518	0,0000
DUS	-0,00347737	0,01609895	-0,216	0,8290
ERF	-2,12625643	0,00836574	-254,162	0,0000
FDH	-2,63059719	0,01124297	-233,977	0,0000
FKB	-3,00967438	0,01485083	-202,660	0,0000
FMO	-1,80783837	0,00726365	-248,888	0,0000
FRA	-0,45199540	0,07953322	-5,683	0,0000
HAJ	-0,52195067	0,00411212	-126,930	0,0000
HAM	-1,25856110	0,00669288	-188,045	0,0000
HHN	-5,12413269	0,05643028	-90,805	0,0000
LEJ	-1,30979383	0,00511335	-256,152	0,0000
MUC	0,36605036	0,02320172	15,777	0,0000
NUE	-0,36324341	0,00477424	-76,084	0,0000
PAD	-1,58827321	0,00705161	-225,235	0,0000
SCN	-1,84378479	0,01153095	-159,899	0,0000

R2 = 0,55886

No. obs. = 11285

Tab. 4: Logit Model Estimation Results of Airport Choice of the Intercontinental Private Travel Market Segment

Variable	Coefficient	Standard Error	t-ratio	p-value
Time	-0,03691192	0,488039D-04	-756,332	0,0000
Direct	0,02937716	0,00537157	5,469	0,0000
NDest	0,02790511	0,00129249	21,590	0,0000
BER	-0,69220169	0,01793575	-38,593	0,0000
BRE	-1,09319764	0,01370117	-79,789	0,0000
CGN	-0,93976316	0,00955500	-98,353	0,0000
DRS	-2,07455752	0,01843791	-112,516	0,0000
DTM	-2,83553894	0,01986358	-142,751	0,0000
DUS	-0,37204005	0,03182459	-11,690	0,0000
ERF	-10,30525740	1,00005813	-10,305	0,0000
FDH	-2,94407637	0,02042886	-144,114	0,0000
FKB	-31,21674380	49967,07200000	-0,001	0,9995
FMO	-1,62229919	0,01399526	-115,918	0,0000
FRA	0,43918344	0,15646981	2,807	0,0050
HAJ	-0,51393130	0,00936085	-54,902	0,0000
HAM	-0,36923409	0,01424942	-25,912	0,0000
HHN	-4,94990276	0,16251943	-30,457	0,0000
LEJ	-2,36823616	0,01699933	-139,313	0,0000
MUC	-0,19746535	0,04597951	-4,295	0,0000
NUE	-0,29236317	0,01022746	-28,586	0,0000
PAD	-2,06893102	0,01634664	-126,566	0,0000
SCN	-4,47238148	0,10774708	-41,508	0,0000

R2 = 0,66537

No. obs. = 2650

Tab. 5: Logit Model Estimation Results of Airport Choice of the Intercontinental Business Market Segment

- Conclusions

The two main factors of airport choice in the logit model calibrated so far are the travel time to the airport and the existence of a direct flight connection to the destination airport, with the access travel time having the strongest influence on airport choice. For long haul flights the number of destinations served plays a role, too. The shorter the flight the more passengers choose an airport with a shorter access time. Business travellers are more time-sensitive than private travellers. The existence of a direct flight connection is more important for private travellers than for business travellers and the shorter the flight distance the more important this attribute becomes for international flights.

As was mentioned already, it was not possible to estimate a sensible airport choice model for the European holiday travel demand. This might be due to neglected attributes or a model specification which is too simple. A more sophisticated model approach will be needed for building a tool capable of analysing and forecasting real world situations with a high degree of accuracy. The goodness of fit measures for the five market segments vary strongly, the greater the flight distance the lower is the measure.

9. Outlook: An Advanced Airport and Access Mode Choice Model – The Neural Nested Logit Model

- Introduction

The logit model is a rather simple approach to describe functionally airport choice behaviour of air passengers. The focus has been on airport choice without considering access mode choice. In many cases airport choice and access mode choice are not independent, but the former depends on the latter choice. More advanced models combine therefore airport and access mode choice; for this approach to be fruitful a nested logit model is a methodological alternative as this approach takes into account interdependencies between choices (for an overview of logit and nested logit methodology with reference to transportation problems see for example Ben-Akiva and Lerman 1985 or Ortúzar and Willumsen 2001). The combined choice is structured in a two or three steps hierarchy with the airport choice on the higher and the access mode choice on the lower level. The access mode choice might be one or two steps, depending on the number of modal alternatives. If there are many alternatives, a distinction between private and public transport is sensible because of interdependencies between similar modes of transport. For example a person who prefers in the first place to take the private car might strongly favour to go by taxi as a second choice instead of taking the bus or train. In general a person might either strongly favour the alternatives of individual transport or those of public transport.

In his doctoral thesis M. Gelhausen goes a step further to combine the nested logit model with neural networks to describe the utility function in a very flexible way. To represent the interdependencies between similar alternatives in a discrete choice model is a rather fundamental problem, another topic, however, is the functional specification of the utility function. This is usually a priori unknown and for simplicity a linear-in-parameters utility function is often chosen. But economic and psychological theory suggests a nonlinear form and empirical research in the field of travel behaviour underlines this fact (see Koppelmann 1981). The Box-Cox-Transformation (see Gaudry 1981) is one step towards a nonlinear utility function, but it does not enable to model arbitrary nonlinear interdependencies between the different attributes nonparametrically. Neural networks as one nonparametric method have been successfully applied to travel mode choice problems, which confirms the assumption of nonlinear interdependencies between the attributes affecting choice (see Hugo 2000). There are many nonparametric methods to approximate functions to an arbitrary degree of accuracy, but neural networks have proven to be powerful in this field and are capable to be combined well with the nested logit model as we will see later. Gelhausen calls his new model "Neural Nested Logit Model" (NNL) and it is described two chapters later. The next chapter deals with the empirical problem to be solved.

- A Combined Airport and Access Mode Choice Model

As mentioned above, the choice of an air traveller choosing an airport to get to his destination can be decomposed into different steps. First, he has to choose an airport to fly from. This decision will be in first place determined by the availability of flights to the destination chosen from this particular airport. This is a K.O.-criterium. If his destination cannot be reached, the traveller will most likely not choose that airport. Of course it is very difficult to build a nested logit model based on single destinations. This would be a model with an unmanageable number of possible alternatives and every alternative would have an infinitesimal small probability to be chosen. Unless an analysis of single destinations is the aim, this approach would not be sensible. In the combined airport and access mode choice model destinations are grouped in domestic, European and intercontinental air traffic. Furthermore these segments are divided into business travel and private travel. Private travel might be subdivided into short trips, which last up to four days, and holiday trips, which last longer than four days.

An important attribute is the availability of a direct flight to the destination from an airport. As found in the model above this has a significant impact on airport choice. The number of destinations into the regions mentioned above serves as an attribute which describes one aspect of the attractiveness of the airport. Destination frequency is another attribute which describes the attractiveness of an airport. Although the passenger is interested only in one flight at his preferred time, the higher the destination frequency, the higher is the possibility that the passenger finds “his” destination at “his” time. The flight price might be another important influence on the air traveller’s choice behaviour, but it is very difficult to measure, as for a discrete choice model prices of the chosen and of all not chosen alternatives are needed. Because it is difficult to find comparable flights at every airport concerning the level of service, destination airport, flight date and time, etc., this approach is hardly possible. Instead the model includes auxiliary variables to model the influence of the flight price on air traveller’s choice behaviour. This could be a variable measuring the general price level of a given airport. Although the air passenger is only interested in “his” flight price, the lower the general price level, the greater is the possibility that he chooses this airport.

Furthermore, the airports are divided into groups of similar airports. This is done for various reasons:

- This approach is based on the theory to be verified that air passenger’s airport choice behaviour is different depending on the type of airport (for example low cost airport vs. hub airport).
- If this theory is appropriate, it allows the model to be used for other airports than it was estimated for, and the airports have to be assigned to these groups. This is the main advantage of discrete choice models: They are based on a behavioural model of choice and this is more stable across regions and time. To conduct an air traveller survey is very expensive. With this approach airports can be analysed without conducting new surveys. The assignment is done with self-organizing maps (see Kohonen 2001). Discriminating factors are airport properties, which play a role for airport choice from a view of the air traveller.
- It reduces model complexity, because the model can be estimated on a subset of the alternatives.

Three types of airports were identified:

- Major hubs which mainly serve European and intercontinental destinations. The number of passengers is very high and many airlines serve this airport.
- Medium-sized airports which serve mainly domestic and European destinations. The number of passengers is average and a few or medium number of airlines serves this airport.
- Small-sized airports which serve mainly the domestic market and some European destinations. They have only few passengers and a small number of airlines serves this airport.

Travel time to the airport is another important factor of airport choice. This attribute shows a strong interdependence between airport and access mode choice, because travel time heavily depends on the chosen mode of transportation. Other relevant attributes concerning access mode choice are transport mode frequency and trip costs. Many mode choice models have been estimated in the past and most of them show these attributes as significant (see for example Ben-Akiva and Lerman 1985). The attributes of access mode choice are easier to measure than those of airport choice, which makes it such a unique modelling problem with special difficulties.

- The Neural Nested Logit Model

The NNL is a combination of a nested logit model and neural networks. The nested logit model builds the theoretical behavioural framework of the NNL. Pure neural networks lack explanatory power and act as a black box. This is a problem especially for application cases, where the quality of the forecast cannot be verified by a couple of short-term forecasts. On the other hand the main advantage of neural networks (for an overview about a variety of neural networks see for example Fausett 1994 or Rojas 1996) is their capability to approximate functions to an arbitrary accuracy, in addition they are more stable than for example polynomials (see Hecht-Nielsen 1990). The main idea of the NNL is to model the utility functions as neural networks within a conventional nested logit model. Some research has been done in this direction with modelling the multinomial logit model as neural network (see Bentz and Merunka 2000, Hruschka et al. 2002, Gelhausen 2003) and the empirical results were very promising (see Bentz and Merunka 2000, Hruschka et al. 2002). With the NNL it will be possible to describe arbitrary nonlinear utility functions and correlations between alternatives in the choice set. The base element of the NNL is the neural network utility function (see Fig. 9).

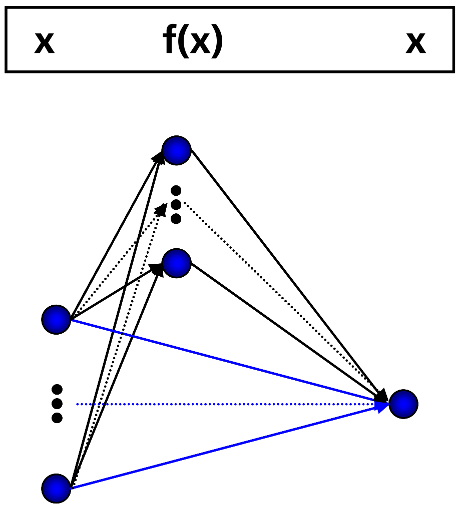

Fig. 9: Neural Network Utility Function

The top box shows the transfer function for the appropriate layer. **f(x)** means any nonlinear differentiable transfer function that is suitable for multilayer perceptrons. The dots indicate further neurons. A three layer neural network is capable of approximating any continuous function as long as it contains enough neurons in his hidden layer (see Hornik, Stinchcombe and White 1989). The input neurons describe the relevant alternative and social attributes of the utility function as in any discrete choice model. The output neuron describes the level of utility.

Fig. 10 shows how the conditional probability of an alternative is computed. There are as many utility functions as there are alternatives in the appropriate nest, the dots in the middle indicate further utility functions. The number of these sub-nets in the NNL equals the number of nests in the nested logit model. Black and blue edges indicate free parameters to estimate while green edges indicate parameters restricted to one. They are necessary to represent the nested logit structure within the neural network.

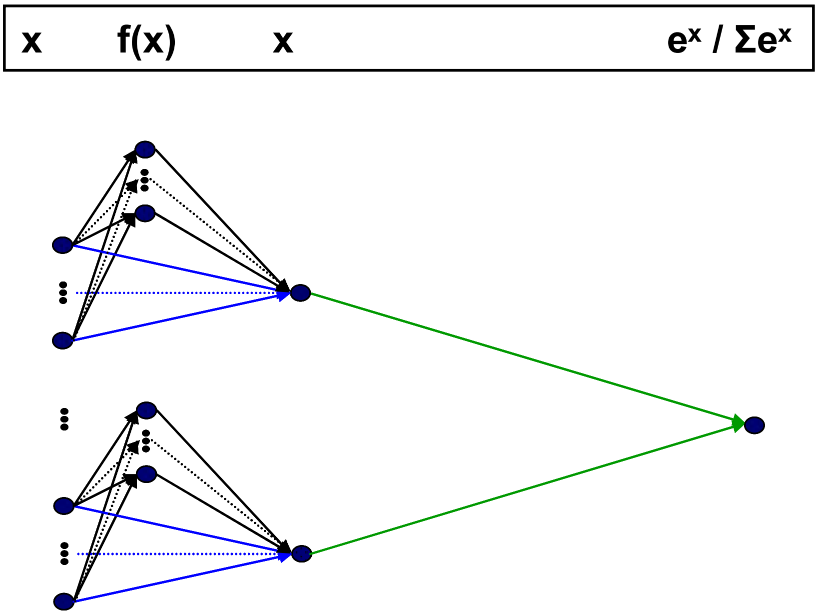

Fig. 10: Conditional Probabilities as Neural Network

Fig. 11 illustrates the sub-net, which computes the expected maximum utility of a nest. There are as many utility functions as alternatives in the nest. The number of sub-nests in the NNL equals the number of nests in the nested logit model. The last two layers have a special transfer function, which is normally not used in a neural network. The e^x-neuron and the ln(x)-neuron are necessary to represent the nested logit structure in this neural network and would be in a conventional neural network not sensible, as these functions are not defined over their entire domain.

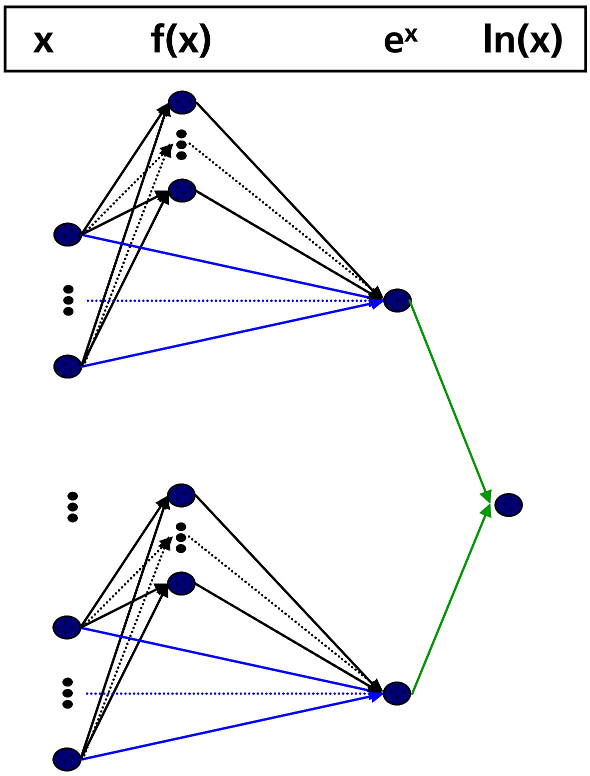

Fig. 11: Expected Maximum Utility as Neural Network

Fig. 12 shows the complete NNL for a two-layer nested logit model. The output neuron has a special transfer function which multiplies all the inputs. Higher nesting structures are possible, but they are difficult to visualize on one page. For understanding the idea a two layer nesting structure is sufficient, because three or more layers are a logical extension of two. In the airport and access mode choice example mentioned above a three layer nesting structure NNL will be used. An important restriction is that all utility functions must have the same structure and the same weights. The learning algorithm is a restricted nonlinear minimization problem. The two kinds of restrictions are:

- The same weights for all utility functions as mentioned above. This is commonly known in the field of neural networks as weight sharing (see Bishop 2003).
- The weights of the green edges are restricted to one.

Neurons and edges must be added or removed to all utility functions in the same fashion to ensure that they are all equal. There can be only a multiple of the number of utility functions added or removed to the NNL. Although the number of neurons is relative high in the NNL, the number of free parameters is low compared to a conventional neural network with the same number of neurons, because the neurons are sparsely connected and the edges underlie a number of restrictions. The strict structure in this kind of neural network follows the idea of adding pre-knowledge to a neural network during its design to enhance the predictive power of a neural network (see Bishop 2003).

Although the NNL is based on a strong theoretical framework it has still to pass the empirical test. An advanced airport and access mode choice model will soon be estimated with the NNL and it will be benchmarked against a nested logit model with a Box-Cox transformed utility function. This will be done for two reasons:

- Can the NNL represent real world problems more accurately than conventional approaches?
- How strong are nonlinear interdependencies between the attributes determining airport and access mode choice?

The first topic is related to the methodology itself and concerns its quality. The second topic is problem-specific and is of empirical interest.

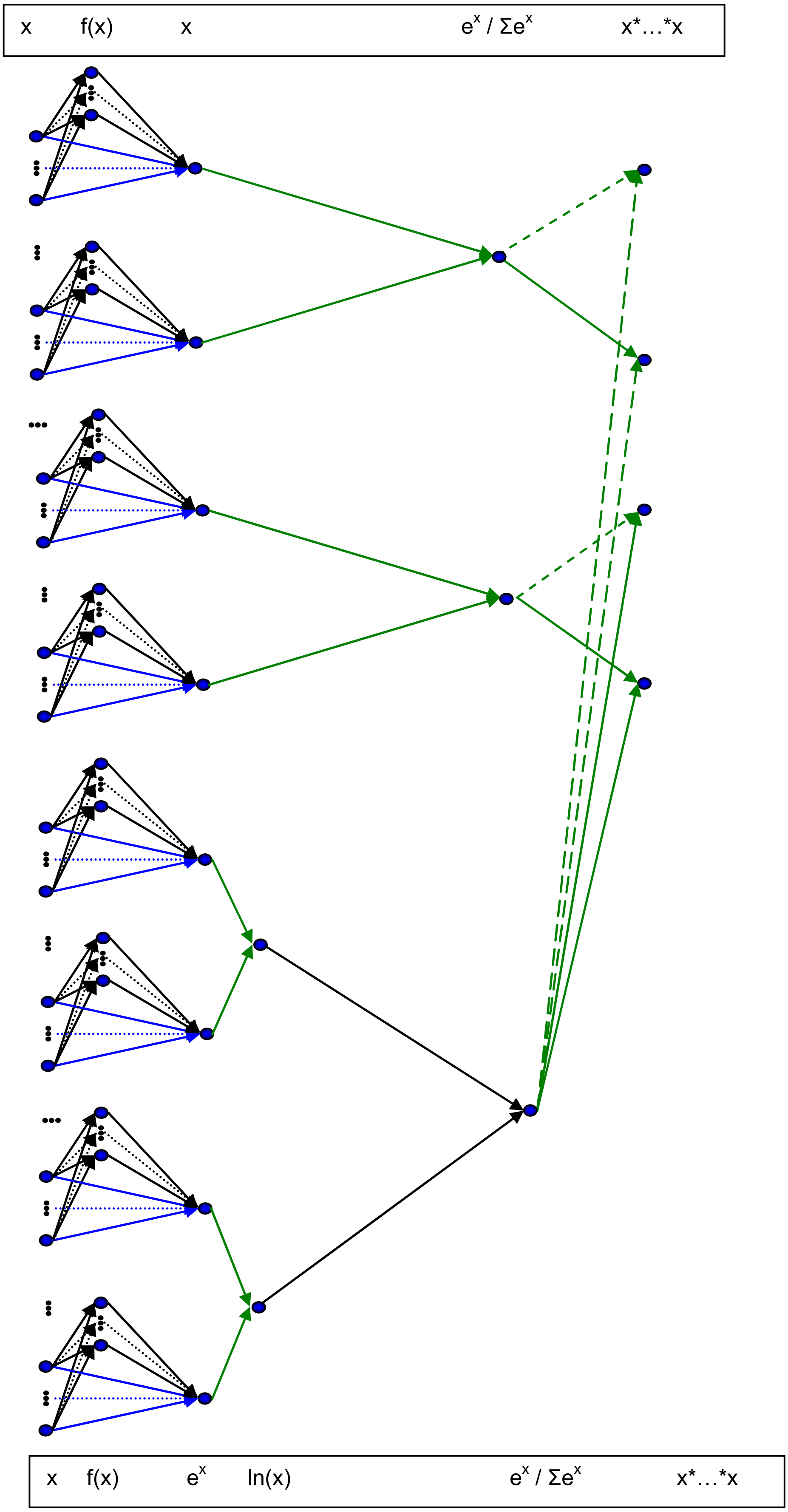

Fig. 12: Neural Nested Logit Model

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