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#84 BUSINESS AVIATION IN GERMANY: AN EMPIRICAL AND MODEL-BASED ANALYSIS

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ABSTRACT

The primary role of international airports is to serve the general public with scheduled and charter services, typically provided by airlines. Of secondary importance is their task to provide direct air transport access to the regional industry and to firms who operate their own fleets. In Düsseldorf (DUS), a major international airport in Germany with about 230 Thousand air transport movements (ATMs) in 2007, about 15 Thousand ATMs belonged to business aviation segment. Due to the complexity of slot allocation procedures and growing runway capacity problems at many international airports, business aviation has a growing problem at these airports to realise the demand for flights. However, neighbouring regional airports could play a complementary role and take over this traffic segment. Therefore, the objective of the paper is to describe and quantify the distribution of the growing business aviation between airports and show potential solutions and further avenues of how to accommodate business aviation at both major and near-by secondary airports. Analysis is supported by means of a new business aviation airport choice model based on a logit approach. This model differs significantly from other airport choice models for regular and tourism traffic in terms of the decision-relevant parameters: Factors such as accessibility of the airport, efficient passenger handling and the length of the runway of secondary airports play an important role, whereas price-related variables are less important to travellers of the business aviation segment. The model enables to develop promising strategies for secondary airports taking over a growing share of the business aviation segment in the case of a neighbouring international airport which suffers from congestion, thereby enhancing the overall level of service in consequence of airport cooperation.

KEYWORDS

Business aviation on main and satellite airports; airport capacity problems; business aviation development; business aviation airport choice model; air traffic distribution between main and satellite airports.

1. Introduction

Air transportation in Germany is handled by a complex system consisting of a relatively large number of airports of varying importance and of many air services with different functions. Like in other countries, the complexity of the air transport system has grown in recent years, amongst others due to the still ongoing liberalisation of markets and the proliferation of services of different kinds of carriers and aircraft operators.

With air traffic growing strongly over the last decades the provision of sufficient airport capacity is becoming a severe problem at some major airports in Germany, like in Frankfurt and Düsseldorf. There are many airports in Germany that have still substantial capacity reserves, these airports, however, handle typically relatively small traffic volumes as compared to the major airports, in particular Frankfurt, München and Düsseldorf.

Capacity problems in peak hours and even more so over all hours of operation are the cause for traffic shifts in favour of more scheduled air transport movements (ATM's) and less ATM's of non scheduled and general aviation movements, since the latter ones have normally a lower priority of slot utilisation at fully coordinated airports. General aviation and in particular business aviation, which forms part of the general aviation, depend on ad hoc decisions regarding the planning of flights whereas airlines have typically grandfather rights for their flights and thus, a higher priority of slot utilisation. This means that firms are often hindered from realising flights planned on a short term notice at major airports and have to look for other dates or other airports nearby in order to carry out the flights needed to pursue their business.

This paper deals with the business aviation situation in Germany by looking into the traffic by type of traffic at some major and satellite airports and with a model which describes the choice between major and satellite airports of business aviation . The paper consists of two principal parts, that is the description of

- the development and structure of business aviation and total traffic at some major airports with capacity problems and their satellite airports,
- an airport choice model for business aviation, whereby the choice set consists of the major airport preferred so far and one or more satellite airports in the case of growing capacity problems at the major airport.

1. Business Aviation and Total Traffic at Major Airports and Their Satellite Airports

1.1 Airport and Air Traffic Structure in 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 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, provided by full service network carriers and to a growing degree by low cost carriers. The international airports handle most of this traffic, although on some of the regional airports traffic volumes are exceeding one million passengers per year.

In addition there are many small airports or airfields which serve primarily general or specialized aviation with small aircraft. To a great deal, these airfields are not equipped to handle scheduled traffic with big passenger or freight aircraft, often on grounds of the runway being too short. Some of these airfields lie in the vicinity of big cities or agglomerations, which are served by an international airport as well. As such they may qualify for taking over complementary functions of the international airport, such as for instance business aviation.

In Fig. 1 the network of international airports of Germany is shown (indicated by the red aircraft symbol). For each of the international airport, traffic volumes in terms of the number of movements, passengers, and tonnes of freight are given for the year 2007. In addition the location of regional airports is marked by a green aircraft symbol.

For the purpose of calibrating a model of airport choice of business aviation, six pairs of major and satellite airports have been selected which are shown by a circle in Fig. 1. These airport pairs are

- Bremen and Ganderkesee,
- Hamburg and Uetersen,
- Berlin and Straußberg,
- Düsseldorf and Mönchengladbach,
- Frankfurt and Egelsbach, and
- München and Landshut.

For the other international airports secondary airfields, which could take over a complementary business aviation function, are further away from the cities being served by the international airport. The satellite airports are named business airport in Fig. 1 and marked by a green aircraft symbol. From the six international airports selected only two airports, Frankfurt and Düsseldorf, have severe capacity shortage during most business hours of the day, while Hamburg and München have capacity problems only during peak hours. Berlin has two international airports, Tegel and Schönefeld, of which Tegel is operating almost at capacity level, whereas Schönefeld has ample capacity. Bremen is one of the smaller international airports of Germany and has no problem of accepting more business traffic.

In 2007, the international airports handled a traffic volume of about 184 million passengers enplaned and deplaned and of almost 2.2 million air transport movements) in commercial traffic on mainly scheduled services (Source: ADV). Since 1992, the second year after the reunification of East and West Germany passenger traffic has more than doubled (corresponding to an average annual growth of 5.15 %) and the ATM volume has grown by half the pace of the passenger volume, that is by 55 % (3.0 % annually).

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 53.9 million passengers and 486 thousand commercial flight movements in 2007, of which almost 60 % belonged to the “home carrier” Lufthansa which operates its primary hub there. More than 50 % of all passengers in Frankfurt use transfer flights.

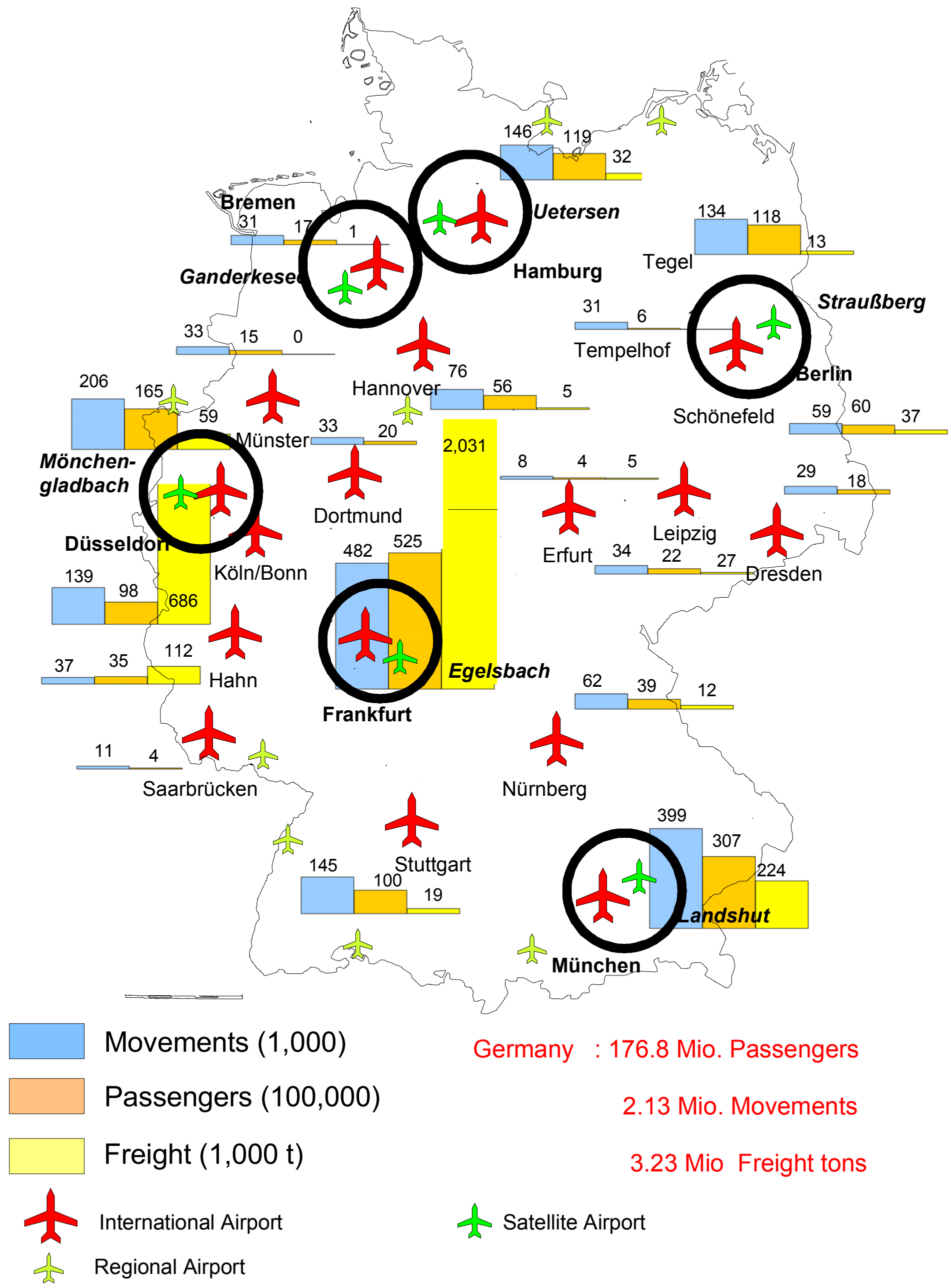

Fig. 1: Airport Network of Germany with Traffic Volumes of 2006

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 34 million passengers and 420 thousand ATMs the second biggest airport in Germany. As a consequence, München airport has expanded the flight volume from 2000 to 2007 by almost 40 %, whereas the total volume of Germany has grown only by 16 % in that period.

In traffic importance following there are another five airports with traffic volumes between around 10 and 18 million passengers, they are Berlin-Tegel (TXL), Düsseldorf (DUS), Hamburg (HAM), Stuttgart (STR) and Köln-Bonn (CGN). All other airports in Germany have rather small traffic volumes. An exception with respect to the traffic function is Hahn airport which is a pure low cost carrier airport, served by Ryanair; the airport is located in a rural region and was formerly a military airfield.

Commercial air traffic in Germany is thus rather concentrated on a few airports, Frankfurt alone accounts for almost 30 % of the total passenger volume of Germany, and the two hub airports FRA and MUC for almost half of the total traffic (48 %). The seven airports of Frankfurt, München, Düsseldorf, of Berlin (being an airport system), Hamburg, Köln/Bonn and Stuttgart with the highest traffic volumes handle almost 160 million passengers, which make up for almost 87 % of the total traffic. Only these airports have already now or face in the near future capacity problems (with the exception of Köln/Bonn), the other 10 international and the regional airports, which carry less than a quarter of the traffic, have sufficient capacity surplus.

1.2 Traffic Development and Structure at Selected Major and Satellite Airports

In the following air traffic is described in terms of ATM's, since business aviation is statistically measured in movements only. Air traffic at the international airports is composed of commercial and non-commercial ATM's, with (commercial) scheduled and charter traffic forming the biggest part of total traffic. Business aviation is composed of movements with company owned aircraft (being non-commercial traffic) and airline operated aircraft (called taxi traffic, being commercial traffic). While in 2007 the total traffic volume of the international airports reached a level of 2.5 Mill. ATM's, of which 2.0 Mill. ATM's belonged to scheduled and charter traffic, the total business traffic amounted to only about 0.2 Mill ATM's. Business aviation is not concentrated on international airports such as scheduled traffic, but uses regional airports and smaller airfields as well, as long as the infrastructural needs like sufficiently long runway and – if possible – ILS are given.

Big business firms rely more than smaller companies on business flights performed either with aircraft owned by the company or chartered aircraft from airlines (taxi flights). Many of these big firms have their head quarters in urban agglomerations rather than in smaller towns, although some big companies and medium sized companies have traditionally their production and administration facilities in smaller cities or even small towns. Often depending on the personal interest of the owner a firm uses own aircraft for business flying or charters business flights from specialized airlines. The tendency to use private or chartered business aircraft, more and more business jets, grows with the existence and proximity of an airport or airfield equipped with a runway long enough and air navigation facilities like ILS to allow operations of business aircraft. Just as big firms use their own fleet for business flying they rely as well on scheduled services of airlines being offered from international airports.

Business aviation in Germany has not developed in the past as positively as the scheduled and charter traffic offered by airlines. While scheduled and charter traffic of airlines grew in the decade of 1997 to 2007 from 1.73 Mill. to almost 2,2 Mill. ATM's on all airports, the number of business flights decreased in the same time from 0.38 Mill. to 0.27 Mill. ATM's. It was in particular the number of flights operated with company owned aircraft that decreased whereas the number of taxi flights stayed constant at a level of about 0.1 Mill ATM's per year.

In Fig. 2 the development of air traffic from 1995 to 2007 at the six selected major airports is shown, and in Fig. 3 the corresponding traffic development at the satellite airports of these major airports is shown, however, with a different scale in order to reflect the great difference in traffic volume.

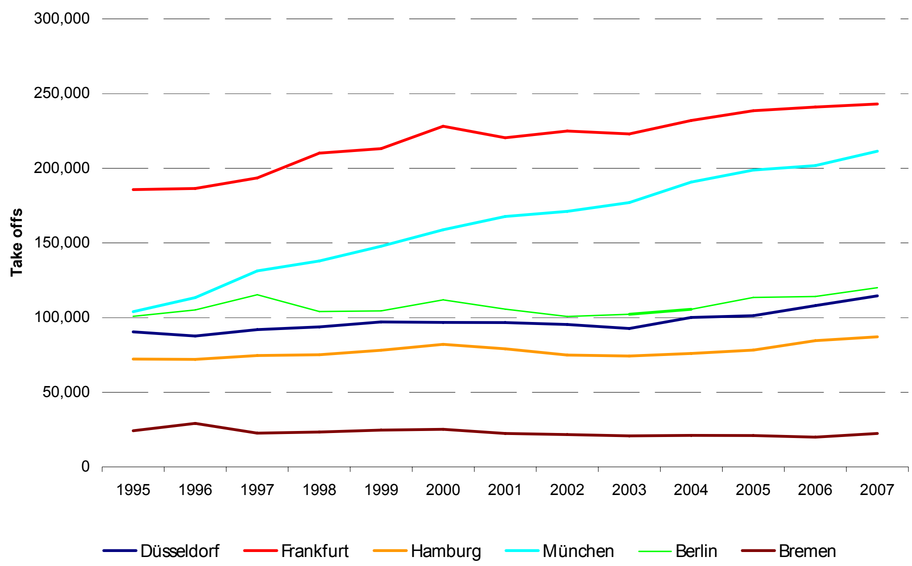

Fig. 2: Development of Air Traffic (Take offs) at Selected Major Airports in Germany (Source: Statistisches Bundesamt, 1995 – 2007)

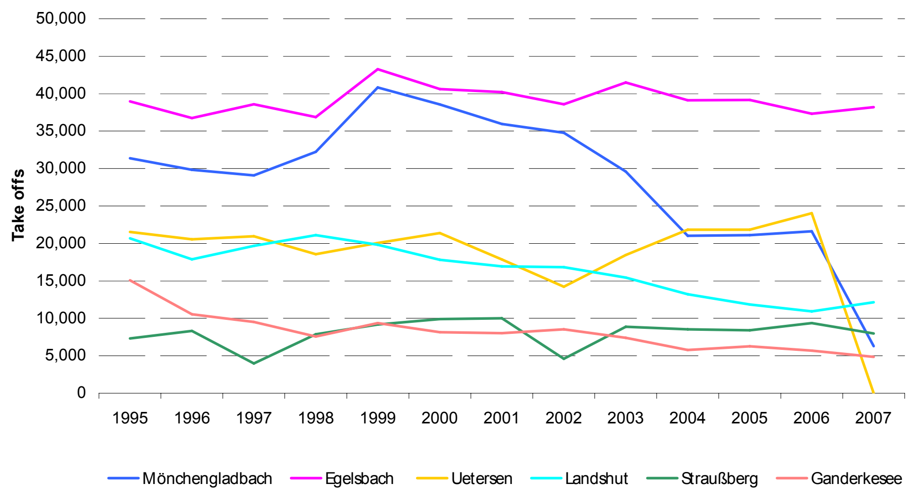

Fig. 3: Development of Air Traffic (Take offs) at Selected Satellite Airports in Germany (Source: Statistisches Bundesamt, 1995 – 2007)

While the traffic at major airports has grown at all airports, with the exception of the smallest airport, Bremen, traffic at the neighbouring small airports has either not changed, e. g. in Egelsbach, Ütersen, and Straußberg, or has declined down, as in Mönchengladbach, Landshut, and Ganderkesee. Even the satellite airport with the highest traffic volume, Egelsbach with around 80 Thousand ATM's per year, has only a small fraction of the traffic of the neighbouring major airport Frankfurt. Since the small airports are typically airports with a single runway, the annual capacity of which may be in the order of 150 Thousand ATM's and more, depending on the existence of navigational aids, they have partly abundant capacity available to take over more traffic, in particular general and business aviation.

In contrast to the capacity reserves of the satellite airports the most heavily charged major airports lack capacity, especially Frankfurt and Düsseldorf, but also München, Hamburg, and

Berlin in peak hours. In order to see the potential of traffic that could be transferred – at least theoretically – we have to look at the business traffic movements at these selected airports. Fig. 4 gives the development of business traffic (take offs) at the major airports, while Fig. 5 shows the corresponding traffic at the small airports.

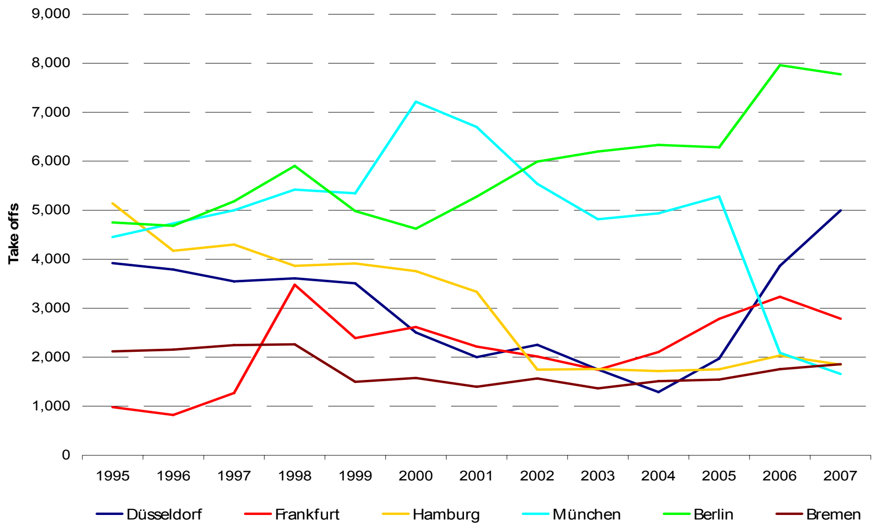

Fig. 4: Development of Business Air Traffic (Take offs) at Selected Major Airports in Germany
(Source: Statistisches Bundesamt, 1995 – 2007)

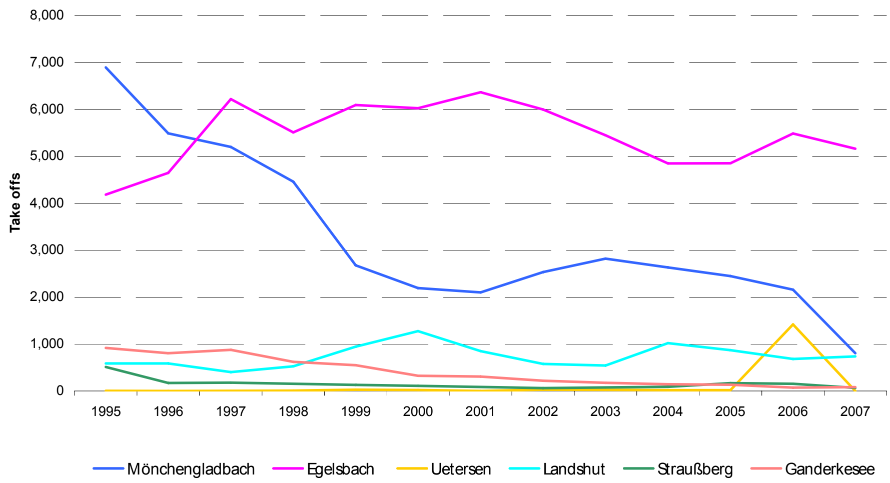

Fig. 5: Development of Business Air Traffic (Take offs) at Selected Satellite Airports in Germany
(Source: Statistisches Bundesamt, 1995 – 2007)

A comparison of business traffic at the major and their satellite airports shows that the number of ATM's is in the same order of magnitude, and that there has been no growth of business traffic at almost all airports.

Frankfurt is the airport which has the highest traffic volume in Germany, but has also a severe capacity shortage as is indicated by the comparatively low traffic growth in the last years (see

Fig. 2). The capacity problem of Frankfurt is clearly demonstrated in Fig. 6, which shows the traffic distribution over the day for the week from 22 to 28 September in 2008.

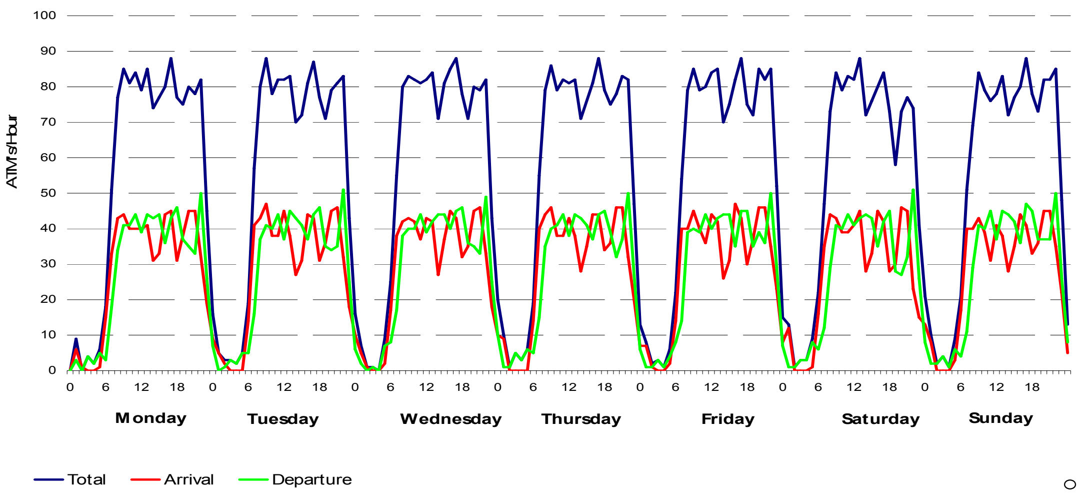

Fig. 6: Hourly Traffic Distribution at Frankfurt Airport, 22 – 28 Sept. 2008
(Source: OAG Data, DLR)

In most hours of the day both the number of take offs and landings reaches levels that are near or at the capacity limit, so that in total the hourly volume varies between 80 and 90 ATM's at week days, with a coordinated capacity of 83 movements per hour (as set forth by the flight plan coordinator of Germany). In spite of the utilisation of the airport at almost capacity level there still around three thousand movements of business flights, which could easily be handled in Egelsbach, assuming that the companies that are responsible for these flights have also an interest to operate from the satellite airport. Egelsbach handles about ten Thousand business flights (ATM's) a year within a total volume of 80 Thousand ATM's.

The situation has been similar in Düsseldorf although the capacity, which is administratively fixed, has been augmented in 2006 from 38 to 45 movements per hour, so that both more passenger and business flights could be accommodated. Due to the previous shortage in slots traffic picked up shortly after the capacity increase (see Fig. 2). In contrast, traffic at the satellite airport Mönchengladbach fell sharply (see Fig. 3 and 5). The gain in capacity will not hold on for long if traffic demand grows again, so that the airport company of Düsseldorf has an interest to shift business flights to Mönchengladbach so as to free slots and make them available to airlines which will use them with bigger aircraft and thus pay higher landing fees to the airport.

In a recent study on behalf of the Düsseldorf airport (DLR, 2008) on future prospects of the satellite airport Mönchengladbach, which is partly owned by the Düsseldorf airport company, the flights performed in business aviation in Düsseldorf were ranked by aircraft type. For each aircraft type of business aviation the necessary runway length requirements for landings and take offs according to the European JAR-OPS were determined so that the runway length of the satellite airport may be decided upon in relation to aircraft type and the probable occurrence of flights by type (see Table 1).

Rank	Aircraft Type	ICAO-Type	Seats	MTOW (t)	Min. Runway Length	
					Take offs	Landings
1	Gates Learjet 55	LR55	8	9.8	1,384	2,845
2	BAE (HS) 125	HS25	15	13.3	1,713	2,287
3	Gates Learjet 60	LR60	9	10.5	1,634	1,885
4	Dassault Falcon 50	DA50	10	17.6	1,365	1,800
5	Dassault Falcon 900 EX	DA90E	19	21.9	1,590	1,790
6	Beech Jet 400	BE40	9	7.3	1,307	1,785
7	Canadair Challenger CL60	CL60	19	19.6	1,645	1,677
8	Gulfstream 5	G5	19	40.4	1,678	1,627
9	Gulfstream 4	G4	19	31.6	1,554	1,625
10	Cessna Citation 560XL Ex.	C56X	10	9.1	1,095	1,617
11	Cessna Citation CJ2	C525A	6	5.6	1,051	1,612
12	Dassault Falcon 20	DA20	10	13.1	1,450	1,588
13	Dassault Falcon 2000	DA22	19	16.3	1,646	1,588
14	Gates Learjet 35	LR35	6	6.2	1,287	1,562
15	Cessna Citation 525 J	C525	6	4.6	977	1,542
16	Gates Learjet 45	LR45	10	8.9	1,280	1,518
17	Gates Learjet 31	LR31	10	7.5	893	1,490
18	Cessna Citation 5	C560	8	7.2	963	1,483
19	Beech Super King Air 300	BE30	15	5.7	411	1,477
20	Cessna Citation 3	C650	9	10.1	1,579	1,473
21	Bombardier Global EX	BD700	19	44.4	1,887	1,357
22	Cessna Citation Souvereig	C680	12	13.6	1,126	1,347
23	BD 100 Challenger	CL30	12	17.5	1,450	1,325
24	Raytheon 390 Premier	PRM1	7	5.7	915	1,292
25	Piaggio Avanti	P180	8	4.9	868	1,250
26	Dassault Falcon 900	DA90	19	20.6	1,515	1,167
27	Cessna Citation 2	C550	10	6.8	727	1,153
28	Beech 200 Super King Air	BE20	13	5.7	566	1,087
29	Piper Cheyenne III	PA42	9	5.5	709	887
30	Piper Chieftrain, Navaho	PA31	9	4.3	415	819

Table 1: Business Aircraft Types at Düsseldorf Airport in 2007
and Runway Length Requirements
(Source: DLR, 2008)

In Fig. 7 the number of flights by aircraft type and the necessary runway length are plotted. The function gives the relative amount of traffic that can be expected if the runway exceeds a certain length. The airport of Mönchengladbach has for instance a runway which is 1200 m long. As can be seen in Fig. 7, only a small fraction of the business aviation of Düsseldorf can be shifted over to Mönchengladbach because the runway is too short. With a prolongation to about 1800 m about 90 % of the business movements of Düsseldorf could theoretically be transferred to Mönchengladbach.

As can be seen in Table 2 (in Chapter 2.2) three of the satellite airports have runways that are shorter than 1000 m so that because of these infrastructural limitations the possibility for transferring business flights is limited to more or less only propeller aircraft.

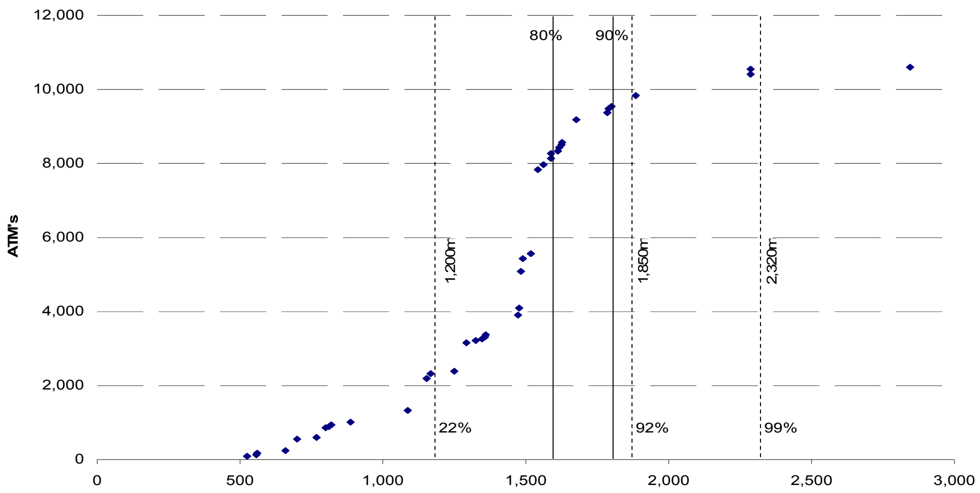

Fig. 7: Business Flights by Aircraft Type in Düsseldorf 2007
and Runway Length Requirements
(Source: DLR, 2008)

As mentioned before, the airports of Hamburg and München have also shortage of capacity in peak hours so that a shift of business flights to the satellite airport may be of interest. Uetersen as the satellite airport of Hamburg has no business traffic, probably because the runway is too short. A prolongation would be necessary if Uetersen should be in a position to take over jet aircraft movements in business aviation. Landshut, the satellite airport of München, has a similar runway problem, in the past, however, München did not have a capacity problem, so that there was no need to shift business traffic. Similarly, Bremen airport has no interest to shift traffic to other airports, on the contrary, Bremen is interested to attract more traffic since the airport has substantial capacity reserves.

Primarily for the Frankfurt and Düsseldorf case the empirical data have been collected in order to develop an airport choice model in business aviation which is dealt with in the following part of the paper.

2. Business Aviation Airport Choice Model

2.1 Basic Theory of Discrete Choice Models

The fundamental hypothesis of discrete choice models is the assumption of individual utility maximisation. The decision maker is assumed to rate alternatives of his choice set by means of a particular utility function and to choose the one with highest utility. From an outside perspective, however, utility of an alternative for a specific individual represents a random variable, therefore, utility U_i for alternative i is decomposed into a deterministic component V_i and a random component ε_i:

(1) $$U_i = V_i + \varepsilon_i$$

The random component of the utility function is introduced for various reasons, i.e. incomplete observability and measurability of the decision-relevant alternative attributes (Maier et al. 1990, pp. 98ff.; Manski 1977, p. 229).

Hence, from an external point of view, only evidence in terms of the probability of an alternative being the one with highest utility is possible. However, on a higher level, these choice probabilities represent segment-specific alternative market shares. Figure 8 illustrates the concept of discrete choice models before going into more technical detail.

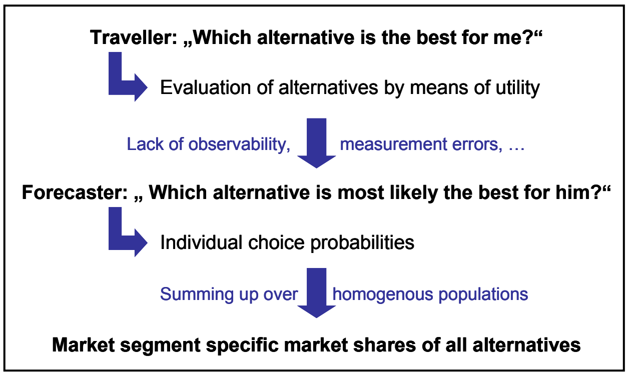

Fig. 8: Approach to Discrete Choice Modelling

Different concepts of discrete choice models differ in terms of their specification of the random component. The most prominent member is the logit-model with independently and identically distributed random components. The choice probability of an alternative i is computed as (Train 2003, p. 40):

(2) $$P_i = \frac{e^{\mu V_i}}{\sum_j e^{\mu V_j}}$$

The scale parameter of the Gumbel distribution is usually fixed to a value of one to enable identification of the model parameters of the utility function (Ben-Akiva and Lerman 1985, S. 107).

In case of a binary choice, i.e. between only two alternatives, (2) reduces to:

(3) $$P_i = \frac{1}{1 + e^{V_j - V_i}}$$

Equitation (3) highlights the close relationship between a binary choice logit model and the logistic regression (Backhaus et. al. 2008, pp. 426ff.):

(4) $$P_i = \frac{1}{1 + e^{-z_i}}$$

Here, z_i comprises decision-relevant variables according to the deterministic part of the utility V_i of the logit model.

As a result of the assumption of independently and identically distributed random components of utility the ratio of two choice probabilities depends only on the utility of those two alternatives (Ben-Akiva et al. 1985, p. 108):

(5)
$$\frac{P_i}{P_j} = \frac{e^{\mu V_i} \Big/ \sum_k e^{\mu V_k}}{e^{\mu V_j} \Big/ \sum_k e^{\mu V_k}} = \frac{e^{\mu V_i}}{e^{\mu V_j}}$$

This property of the logit-model is called "Independence from Irrelevant Alternatives" (IIA) and it represents both a weakness and strength of the model. Due to the distribution assumptions of the random component of utility it is therefore not possible to model any correlations among alternatives in the choice set owing to unobserved factors. An important benefit of the IIA-property is the potential for estimation of the model parameters on a subset of the alternatives (McFadden 1974, p. 113; McFadden 1978, pp. 87ff.; Ortuzar et al. 2001, pp. 227f.; Train 2003, pp. 52f.) and therefore the possibility to evaluate new or hypothetical alternatives on the basis of the same model without any need of re-estimation of model parameters (Domencich et al. 1975, pp. 69f.). The same is true for the case of binary choice.

2.2 Empirical Data for Model Parameter Estimation

The number of business aviation aircraft movements at selected airports is taken from the German Air Transport Statistics for the time period from 1997 until 2006 (Statistisches Bundesamt 1997 – 2006. Besides providing the number of aircraft movements it serves to determine relative frequencies of airport choice in business aviation. Data on characteristics of the runway of an airport, its technical equipment, like e.g. an instrument landing system and whether service providers and charter businesses are settled at a particular airport are collected on an individual basis (Airports 2009). However, a minimum level of service provided and charter possibilities are necessary so that the last two conditions are fulfilled. For qualification, substantial maintenance services and jet charter for pan-European flights must be offered at a particular airport.

Travel time for persons employed is calculated on the basis of commercial routing software (Microsoft 2003) and regional statistics (Statistisches Bundesamt 2008). This information is supplemented by data on regional GDP and company structure (Statistisches Bundesamt 2008; Hoppenstedt 2009) to account for regional differences in usage of business aviation. Table 2 displays selected statistical characteristics of the data sample employed for model estimation.

Airport	ø Number of Departures 1997 - 2006	ø Relative Frequencies	ø Travel Time per Employee (min)	Length of Runway	ILS available	Charter & Services
Hamburg	2,818	0.95	20.74	3,666	Yes	Yes
Uetersen	156	0.05	44.11	900	No	No
Berlin	5,874	0.98	16.25	3,023	Yes	Yes
Strausberg	120	0.02	52.98	1,200	No	No
Bremen	1,673	0.83	21.42	2,640	Yes	Yes
Ganderkesee	343	0.17	30.01	836	No	Yes
Frankfurt/Main	2,386	0.30	21.55	4,000	Yes	Yes
Egelsbach	5,683	0.70	26.96	1,400	Yes	Yes
Düsseldorf	2,631	0.47	17.11	3,000	Yes	Yes
Mönchengladbach	2,922	0.53	25.63	1,200	Yes	Yes
Düsseldorf	2,631	0.60	17.11	3,000	Yes	Yes
Essen/Mülheim	1,773	0.40	21.76	1,553	No	Yes
Munich	5,233	0.87	33.66	4,000	Yes	Yes
Landshut	769	0.13	48.04	900	No	Yes

Table 2: Statistical Characteristics of Estimation Data Sample (Gelhausen 2009, p. 3)

1.3 Model Specification and Parameter Estimation

Translation invariance represents an important feature of the logit model (Maier and Weiss 1990, pp. 135f.): Adding an identical constant to V_i for all alternatives of the choice set does not change choice probabilities (2). Therefore, choice probabilities of a logit model only depend on differences in utility and they are independent of the general level of utility. Hence, in case of a linear utility function

(6) $$V_i = alt_i + \sum_k b_k * x_{k,i}$$

alt_i: Alternative-specific constant of alternative i
b_k: Coefficient of attribute k
$x_{k,i}$: Value of attribute k of alternative i

choice probabilities depend alone on differences in values of the correspondent attributes of the alternatives in the choice set.

However, with regard to airport choice in business aviation, this is not desirable, as for some variables their level is decision-relevant within some scope. Take e.g. runway length: Up to some critical point runway length is important from the perspective of business aviation at a small regional airport for technical reasons; however, differences in runway length compared to a neighbouring large international airport have no meaning, because runway length is usually not a limiting factor at such an airport. Besides, if runway length exceeds 2,300 m, there are no essential further benefits of an even longer runway from the point of view of business aviation, as almost all types of business jets are able to start and land on a runway of such length (Berster et al. 2008, p. 42). On the other hand, a shorter runway at a large airport does not affect business aviation airport choice just as little as long as runway length keeps above a value of around 2,300 m. However, this would not be representative in a typical multinomial logit model as a reason of translation invariance. Take e.g. Munich/Landshut vs. Bremen/Ganderkesee in Table 2: The difference in runway length reduces from 3,100 m to 1,834 m by around 41%, but choice probabilities change only by a few percentage points. Without going into too much detail this would be difficult to model in case of translation invariance.

Therefore, a modified binary logit model is employed for business aviation airport choice (Gelhausen 2009): Each single choice set for model parameters estimation comprises a satellite and a large airport and total runway length of the satellite airport is taken as one attribute of the utility function, because runway length of the large airport is supposed not to be a limiting factor in business aviation airport choice. Anyway, it is possible to apply the estimated model to cases of more than two airports as a reason of the IIA-property, which has been described earlier in this paper: The ratio of two choice probabilities depends solely on the attribute values of these two alternatives, hence, for more than two alternatives in the choice set, it is possible to compute all choice probabilities by means of their ratios.

Example: *Take two small airports A and C and a large airport B. Say, the ratio of the choice probabilities are as follows: P(A)/P(B)=1:1 and P(C)/P(B)=2:1. Therefore, P(A)/P(B)/P(C)=1:1:2 and thus the individual choice probabilities are P(A)=0.25, P(B)=0.25 and P(C)=0.5.*

The utility function of the model is of linear form and equals (6). The Maximum-Likelihood Method is employed for model estimation and the Newton algorithm is used for optimisation. The covariance matrix of the estimated model parameters is computed on the basis of the inverted negative Hessian. NLOGIT 3.0 is used as econometric software package (Econometric Software 2002). Table 3 shows the results of parameter estimation.

Variable	Coefficient	Standard Deviation	t-value	p-value
SAPT	-1.69984	0.259681	-6.54587	5.91E-11
TTEMP	-0.0960844	0.00604232	-15.9019	2.89E-15
ILS	1.35334	0.029415	46.0084	2.89E-15
SERVICE	0.0326469	0.132733	0.24596	8.06E-01
RWY	0.0011402	8.89E-05	12.8331	2.89E-15

Table 3: Estimation Results (Gelhausen 2009, p. 4)

The alternative-specific constant of “large airport” has been set to a value of zero and the scale parameter μ has been fixed to a value of one to enable parameter identification in the estimation process. “VLP” represents the alternative-specific constant for a satellite airport. “TTEMP” refers to the travel time difference in minutes for an employee between a satellite and a large airport. ILS is a binary variable to describe whether an instrument landing system is available at the small airport. “Service” is a binary variable which refers to service and charter opportunities as already described earlier in this paper. “RWY” represents the runway length in meters of a satellite airport.

All variables of the final model specification are highly significant at least at a significance level of 1%. As a reason of maximum likelihood estimation, model quality is assessed by means of the so-called pseudo-R^2 (Domencich and McFadden 1975, pp. 123f.; Hensher et al. 2005, p. 337):

(7)
$$\rho^2 = 1 - \frac{LL^U}{LL^R}$$

LL^U and LL^R represent values of the log-likelihood function of unrestricted and restricted model, respectively. A restricted model only with alternative-specific constants is chosen in this paper.

The final model estimated shows a pseudo-R^2 of 27.73% which equals an R^2 of linear regression of around 65% (Domencich and McFadden 1975, pp. 123f.) and this is a quite satisfying result given the problem structure (Hensher et al. 2005, pp. 338f.). However, airport choice in business aviation is also governed by some random factors which are hard to predict ex ante. Table 4 shows average differences between relative frequencies of the sample and computed choice probabilities of the model per airport pair (small/large).

Airport	Relative Frequencies	Model Values	Difference
Hamburg	0.9475	0.9487	-0.0012
Uetersen	0.0525	0.0513	0.0012
Berlin	0.9800	0.9794	0.0006
Strausberg	0.0200	0.0206	-0.0006
Bremen	0.8299	0.8234	0.0065
Ganderkesee	0.1701	0.1766	-0.0065
Frankfurt	0.2957	0.3180	-0.0223
Egelsbach	0.7043	0.6820	0.0223
Düsseldorf	0.4738	0.4414	0.0324
Mönchengladbach	0.5262	0.5586	-0.0324
Düsseldorf	0.5974	0.5850	0.0124
Essen/Mülheim	0.4026	0.4150	-0.0124
Munich	0.8719	0.8832	-0.0113
Landshut	0.1281	0.1168	0.0113

Table 4: Relative Frequencies of the Sample vs. Choice Probabilities of the Model (Gelhausen 2009, p. 5)

2.4 Determinants of a Successful Relocation Strategy

Travel time to the airport, length of the runway, availability of an instrument landing system as well as service and charter opportunities were previously identified as the main systematic factors which determine airport choice in business aviation. The purpose of this chapter is to show how a variation of these influencing variables affects airport choice with special regard to small regional airports in detail.

Figure 9 illustrates the relation between runway length and market share of a satellite airport with the difference in travel time fixed to a value of 15 minutes, i.e. the small airport lies 15 minutes further away from the perspective of an average employee. Here, 15 minutes represents the average value of the sample. Runway length of a small regional airport varies between 836 m and 2,300 m. 836 m represents the minimum runway length of the data sample and 2,300 m represents some upper bound from which further extensions are rather unnecessary from the point of business aviation. Figure 9 clearly shows how a longer runway increases the attractiveness of a small airport for business aviation, resulting in a larger market share. The availability of an instrument landing system further increases market share and the average increase lies in a range between 19 and 33 percentage points (mean: 27 percentage points). However, service and charter opportunities have only a small effect on market share (maximum one percentage point).

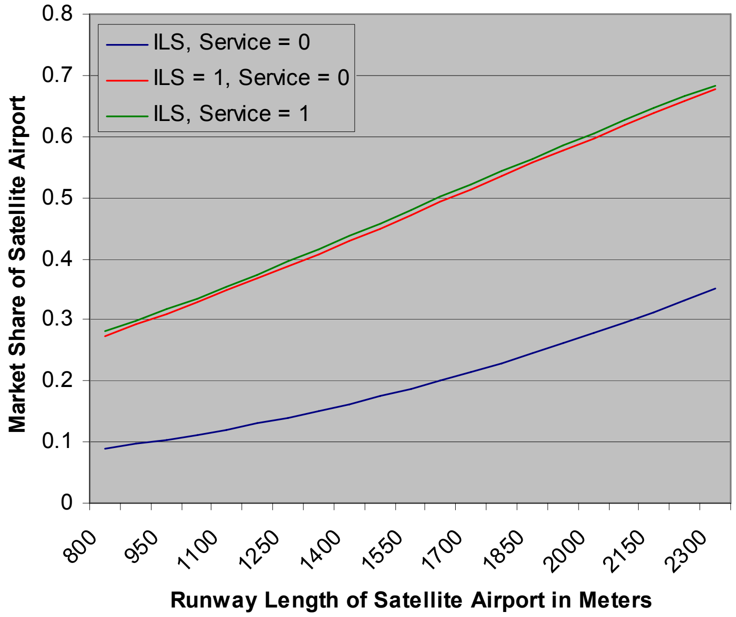

Figure 9: Runway Length of a Satellite Airport and Market Share (Gelhausen 2009, p. 5)

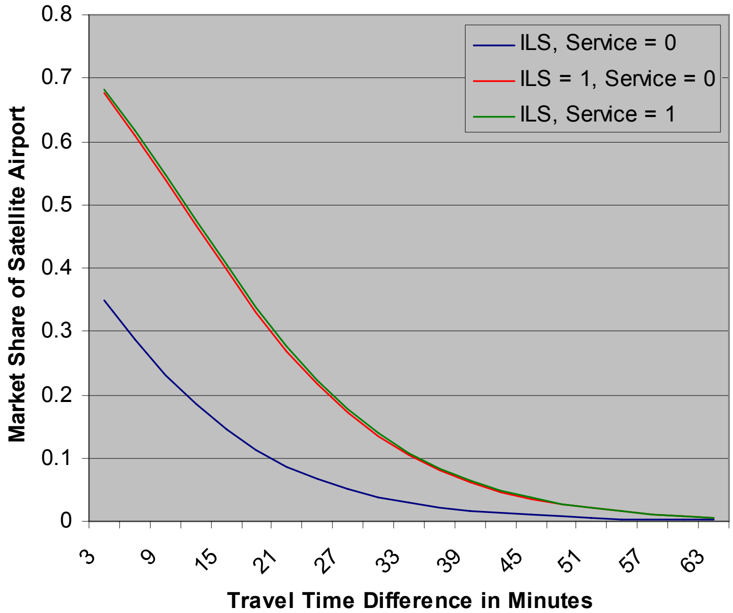

Figure 10: Travel Time Difference and Market Share of a Satellite Airport (Gelhausen 2009, p. 6)

Figure 10 delineates the relationship between difference in travel time and market share for a given runway length of 1,200 m which represents the average runway length of the sample. With increasing travel time compared to the large international airport, market share of a satellite airport falls continuously. If the satellite airport lies about 21 minutes away, market share already falls to a level of about 10% (no instrument landing system) and tends towards zero for a travel time difference of one hour and longer. The availability of an instrument landing system raises market share if travel time difference is not too large at most by 33 percentage points and on average by 12 percentage points over the interval of travel time difference considered. Availability of services and charter possibilities again has only a small effect on market share.

References

Backhaus, K; Erichson, B.; Plinke, W.; Weiber, R. (2008). Multivariate Analysemethoden: Eine anwendungsorientierte Einführung. Springer, Berlin.

Ben-Akiva, M.; Lerman, S. (1985). Discrete Choice Analysis: Theory and Applications to Travel Demand. MIT-Press, Cambridge.

Berster, P.; Gelhausen, M. Ch.; Pabst, H.; Reichmuth, J.; Wilken, D. (2008). Aktuelle Situation und Entwicklungsperspektiven für den Flughafen Mönchengladbach. DLR, Köln.

DLR (2008). Aktuelle Situation und Entwicklungsperspektiven für den Flughafen Mönchengladbach, Study on behalf of Düsseldorf Airport, Köln, 2008 (unpublished).

Domencich, T. A.; McFadden, D. (1975). Urban Travel Demand – A Behavioral Analysis. Elsevier, New York.

Econometric Software (2002). NLOGIT Version 3.0 Reference Guide. Econometric Software, Plainview.

Airports (2009). Various information brochures of airports. Various cities.

Gelhausen, M. Ch. (2009). Ein Logit-Modell zur Flughafenwahl in der Business Aviation. Proceedings of Deutscher Luft- und Raumfahrtkongress 2009, pp. 1 – 6. Aachen, Germany.

Hensher, D. A.; Rose, J. M.; Greene, W. H. (2005). Applied Choice Analysis – A Primer. Cambridge University Press, Cambridge.

Hoppenstedt (2009). Firmendatenbank Deutschland. Hoppenstedt, Darmstadt.

Maier, G.; Weiss, P. (1990). Modelle diskreter Entscheidungen – Theorie und Anwendung in den Sozial- und Wirtschaftswissenschaften. Springer, Wien.

Manski, C. F. (1977). The Structure of Random Utility Models. Theory and Decision 8, pp. 229 – 254.

Microsoft (2003). Microsoft AutoRoute 2003.

McFadden, D. (1974). Conditional Logit Analysis of Qualitative Choice Behavior. In: Zarembka, P.: Frontiers in Econometrics, pp. 105 – 142. Academic Press, New York.

McFadden, D. (1978). Modelling the Choice of Residental Location. In: Karlqvist, A.; Lundqvist, L.; Snickars, F.; Weibull, J.: Spatial Interaction Theory and Planning Models pp. 75 – 96. Elsevier, Amsterdam.

Ortuzar, J. de D.; Willumsen, L. G. (2001). Modelling Transport. Wiley & Sons, London.

Statistisches Bundesamt (1997 – 2006). Luftverkehrsstatistik. Statistisches Bundesamt, Wiesbaden.

Statistisches Bundesamt (2008). Statistik regional. Statistisches Bundesamt, Wiesbaden

Train, K. E. (2003). Discrete Choice Methods with Simulation. Cambridge University Press, Cambridge