THE IMPACT OF HIGH SPEED INTERCITY TRAIN ACCESS ON AIRPORT CHOICE IN GERMANY

Dr.rer.pol. M. Ch. Gelhausen
German Aerospace Center (DLR) - Air Transport and Airport Research
Linder Höhe, 51147 Cologne
Germany

1. INTRODUCTION

The purpose of this paper is to analyse exemplarily the effects of high speed intercity access on airport choice in Germany. The chosen example is airport and access mode choice in the Cologne region, whose demand is mainly served by the airports of Cologne, Düsseldorf and Frankfurt/Main.

The Cologne region is connected with Frankfurt/Main airport by ICE since 2002, so that travel time by train to the airport was roughly cut by 50% compared to the former intercity connection. Frankfurt/Main airport is now only about 60 minutes away from Cologne main station, whereas before travel time was nearly two hours. The share of air passengers taking the train access to Frankfurt/Main airport increased considerably, because of air travellers switching both from the plane and other ground access modes to the ICE. In this study, however, analysis is focussed on air travellers switching from other ground access modes to the train and thus excluding the plane.

Furthermore, the impact of a high speed intercity connection on the competition between the airports serving the Cologne region is analysed. Is it possible for Frankfurt/Main airport to gain significantly market share relatively to the two airports close to the Cologne region, Cologne and Düsseldorf airport, by reducing travel time to the airport? And what is the impact of the supply of flights to a given destination? Do improvements in this area overcast any improvements in access quality?

These questions are analysed by means of a nested logit-model developed by the author (Gelhausen et al. 2006; Gelhausen 2006, 2007) to explain the market share of these airports depending on air travellers' preferences regarding mainly access time, access cost and the supply of low cost and full service flights to a given destination.

Apart from the intercity and ICE access options from Cologne to Frankfurt/Main airport a hypothetical Transrapid access is evaluated. The reason for this analysis is not founded in the technology of the Transrapid, actually any train with the same relevant attributes serving the aforementioned preferences of air travellers could have been chosen. The motivation behind this approach is to show the dependence between access time, access cost and the market share of an airport including access options beyond those already available today, so that some advice for future infrastructure design can be given.

The outline of the paper is as follows:

Chapter 2 is a short summary of the nested logit-model employed for the analysis. The central idea of discrete choice modelling is described with an emphasis on nested logit-models. Subsequently, the airport and access mode choice model with its special properties is explained (Gelhausen et al. 2006).

Chapter 3 contains the analysis of airport and access mode choice in the Cologne region under different circumstances. Three scenarios concerning the train connection between Cologne and Frankfurt/Main airport are evaluated and the impact of a different supply of flights at Düsseldorf airport on regional airport choice is analysed. The chapter concludes with some general analysis on the market share of Frankfurt/Main airport against access time and access cost of the train access to the airport.

The paper ends with some conclusions and a summary.

2. MODEL OVERVIEW

2.1 Theory of Discrete Choice

The fundamental hypothesis of discrete choice models is the assumption of individual utility maximisation. Alternatives are evaluated by means of a utility function and the one with the highest utility is supposed to be chosen. From an external point of view the utility of an alternative for a specific individual is a random variable, so that the utility U_i for alternative i is composed of a deterministic component V_i and a random component ε_i (Maier et al. 1990, p. 100):

$$U_i = V_i + \varepsilon_i \qquad (2.01)$$

The random component of the utility function is introduced for various reasons, i.e. a lack of observability of the relevant attributes of the alternatives or their incomplete measurability (Maier et al. 1990, pp. 98f.).

From an external point of view, only evidence in terms of the probability of an alternative being the one with the highest utility can be given, because of the random component in the utility function. On a higher level, these choice probabilities represent the market segment-specific shares of the alternatives. FIG 2.01 illustrates the idea of discrete choice models before going into more technical detail.

Specific discrete choice models differ in terms of their assumptions of the random component. The most prominent member of this class of models is the logit-model with independently and identically distributed random components.

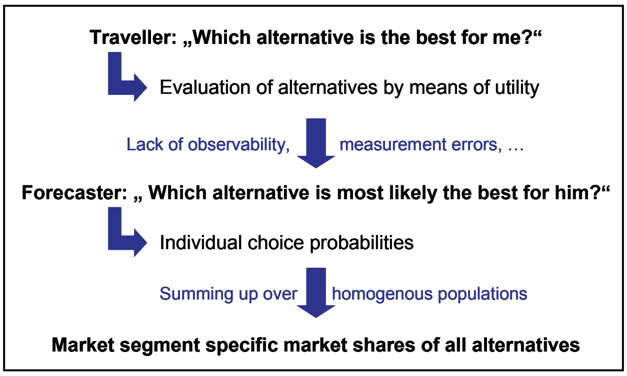

FIG 2.01: Idea of Discrete Choice Models

The choice probability of an alternative i is computed as (Train 2003, p. 40):

$$P(a_i = a_{opt}) = \frac{e^{\mu V_i}}{\sum_j e^{\mu V_j}} \quad (2.02)$$

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

$$\frac{P(a_i = a_{opt})}{P(a_j = a_{opt})} = \frac{\dfrac{e^{\mu V_i}}{\sum_k e^{\mu V_k}}}{\dfrac{e^{\mu V_j}}{\sum_k e^{\mu V_k}}} = \frac{e^{\mu V_i}}{e^{\mu V_j}} \quad (2.03)$$

This property of the logit-model is called “Independence from Irrelevant Alternatives” (IIA) and it is both a weakness and strength of the model. Due to the distribution assumptions of the random component of the utility function it is not possible to model correlations among alternatives owing to unobserved factors. A major advantage of the IIA-property is the possibility to estimate the model parameters, excluding alternative-specific variables, 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 the possibility of an evaluation of new alternatives without the need to re-estimate alternative-unspecific model parameters (Domencich et al. 1975, pp. 69f.).

The nested logit-model relaxes the IIA-restriction to some extent without losing the closed-form expression of the choice probabilities. For this purpose the random component in (2.01) is split up into a part ε_i^a, which varies over all alternatives i and a part ε_k^c, which is identical for all alternatives of a nest k (Maier et al. 1990, pp. 154f.):

$$U_i = V_i + \varepsilon_i^a + \varepsilon_k^c \quad (2.04)$$

It is possible to model correlations due to unobserved factors among subsets of the alternatives, so that the choice set is partitioned into clusters with highly correlated alternatives. (2.05) is an example of a covariance matrix for four alternatives partitioned into two clusters with the first two belonging to cluster one and the last two assigned to cluster two.

$$\Omega = \begin{bmatrix} \sigma_{11}^2(\mu_1^c) & \sigma_{12}^2(\varepsilon_1^c) & 0 & 0 \\ \sigma_{21}^2(\varepsilon_1^c) & \sigma_{22}^2(\mu_1^c) & 0 & 0 \\ 0 & 0 & \sigma_{33}^2(\mu_2^c) & \sigma_{34}^2(\varepsilon_2^c) \\ 0 & 0 & \sigma_{43}^2(\varepsilon_2^c) & \sigma_{44}^2(\mu_2^c) \end{bmatrix} \quad (2.05)$$

Each cluster k is characterized by an individual scale parameter μ_k^c and an identical non-negative covariance for all alternatives i within a cluster k. Alternatives of different clusters are assumed not to be correlated.

For technical reasons the choice probabilities $P(a_i = a_{opt})$ are decomposed into an unconditional choice probability $P(c_k = c_{opt})$ that cluster k is chosen, and a conditional choice probability $P(a_i = a_{opt} \mid a_i \in c_k)$, that alternative i from cluster k is chosen (Maier et al. 1990, p. 156):

$$P(a_i = a_{opt}) = P(a_i = a_{opt} \mid a_i \in c_k) * P(c_k = c_{opt}) \quad (2.06)$$

The conditional choice probabilities comply with the logit-model and the choice set is restricted to the alternatives of the appropriate nest. The choice probability of a nest k is determined by its maximum utility V_k^c (Maier et al. 1990, p. 157):

$$V_k^c = \frac{1}{\mu} \ln \sum_{i \in k} e^{\mu V_i} \quad (2.07)$$

The choice probability of an alternative i in nest k can be written as (Maier et al. 1990, p. 158):

$$P(a_i = a_{opt}) = \frac{e^{\mu V_i}}{\sum_{j \in k} e^{\mu V_j}} * \frac{e^{\mu_k^c V_k^c}}{\sum_l e^{\mu_l^c V_l^c}} \quad (2.08)$$

The hierarchical structure of (2.08) does not imply a sequential decision process. An extension to more than two levels is straightforward (see i.e. Ben-Akiva et al. 1985, pp. 291ff.). Nests are further subdivided into sub-nests. A three-level nested logit-model is employed for this study with an additional conditional choice probability on the middle level based on the maximum utility of the appropriate sub-nest.

2.2 Generalized Nested Logit-Model for Airport and Access Mode Choice

FIG 2.02 illustrates the nesting structure of the employed airport and access mode choice model in an abstract way with the abbreviations explained in TAB 2.01 (Gelhausen et al. 2006, p. 20).

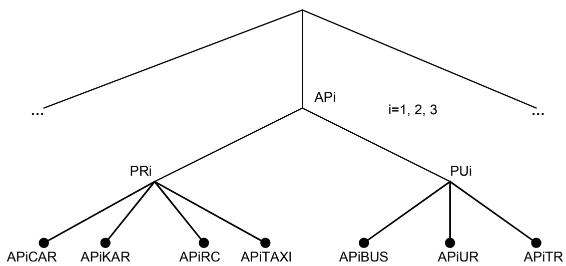

FIG 2.02: Nesting Structure

The airports are on the top level and the airport/access mode combinations are on the lowest level, which are subdivided into private and public modes of access on the middle level. Any number of airports is possible on the top level and any airport/access mode combination is allowed on the lowest level. The abbreviations are explained in TAB 2.01 (Gelhausen et al. 2006, p. 20).

The central building blocks of the model are the three airport categories and the 21 base alternatives, which result from a combination of seven different access modes with three airport categories. For model application, each real airport/access mode combination is assigned to one of the 21 base alternatives, whereby it is possible to apply the model to any airport/access mode scenario as a result of this generalisation mechanism, no matter whether it is real or only hypothetical.

Alternative	Abbreviation
AP 1/Car	AP1CAR
AP 1/Kiss and Ride	AP1KAR
AP 1/Rental Car	AP1RC
AP 1/Taxi	AP1TAXI
AP 1/Bus	AP1BUS
AP 1/Urban Railway	AP1UR
AP 1/Train	AP1TR
AP 2/Car	AP2CAR
AP 2/Kiss and Ride	AP2KAR
AP 2/Rental Car	AP2RC
AP 2/Taxi	AP2TAXI
AP 2/Bus	AP2BUS
AP 2/Urban Railway	AP2UR
AP 2/Train	AP2TR
AP 3/Car	AP3CAR
AP 3/Kiss and Ride	AP3KAR
AP 3/Rental Car	AP3RC
AP 3/Taxi	AP3TAXI
AP 3/Bus	AP3BUS
AP 3/Urban Railway	AP3UR
AP 3/Train	AP3TR

TAB 2.01: Base Alternatives

TAB 2.02 shows the assignment of 22 German airports to airport categories. The next step is to choose the set of airports with their access modes for the analysis to be undertaken and assign them to the base alternatives. In this study for example, all 22 airports were chosen with their access modes as available in 2005 or required by the simulated scenario.

Category	Airport (IATA-Code)
AP 1	Frankfurt a. M. (FRA)
AP 1	München (MUC)
AP 2	Berlin (BER)
AP 2	Düsseldorf (DUS)
AP 2	Hamburg (HAM)
AP 2	Köln/Bonn (CGN)
AP 2	Stuttgart (STR)
AP 3	Bremen (BRE)
AP 3	Dortmund (DTM)
AP 3	Dresden (DRS)
AP 3	Erfurt (ERF)
AP 3	Frankfurt Hahn (HHN)
AP 3	Friedrichshafen (FDH)
AP 3	Hannover (HAJ)
AP 3	Karlsruhe/Baden (FKB)
AP 3	Leipzig/Halle (LEJ)
AP 3	Lübeck (LBC)
AP 3	Münster/Osnabrück (FMO)
AP 3	Niederrhein (NRN)
AP 3	Nürnberg (NUE)
AP 3	Paderborn/Lippstadt (PAD)
AP 3	Saarbrücken (SCN)

TAB 2.02: Assignment of Airports to Airport Categories

Seven market segments are defined by the two dimensions trip purpose and destination type:

- Journeys to domestic destinations, subdivided into private (BRD P) and business (BRD B) trip purpose
- Journeys to European destinations for private short stay reasons up to four days (EUR S)
- Journeys to European destinations for holiday reasons for five days or longer (EUR H)
- Journeys to European destinations for business trip purpose (EUR B)
- Journeys to intercontinental destinations, subdivided into private (INT P) and business (INT B) trip purpose

TAB 2.03 displays the estimated coefficients of the alternative attributes, scale parameters, goodness-of-fit measures and the likelihood-ratio test statistics for all seven market segments (Gelhausen et al. 2006, p. 28).

Variable	BRD P	BRD B	EUR S	EUR H	EUR B	INT P	INT B
COST	-0.0263035	-0.0204609	-0.0199987	-0.0173617	-0.0216885	-0.0138527	-0.00936472
TIME	-0.0081889	-0.0152572	-0.0061063	-0.00857067	-0.00795957	-0.00541014	-0.00535887
WAIT	-28.8061	-18.935	-8.33078	-4.40982	-9.94709	-18.7546	-35.7591
INVPD	-187.86	-21.8829	-215.876	-235.641	x	-25.6109	-32.2589
COMP	-0.158635	x	-1.22176	-1.13258	-0.182127	x	x
AAS	0.920627	1.12781	0.20336	0.46823	0.504623	0.840462	0.382595
DIRECT	2.29637	3.64119	3.63327	3.31697	1.43564	1.85847	0.439344
DFREQ	0.00682913	0.00601159	0.0104684	0.0153856	0.0177437	x	x
LC	x	x	0.0863075	0.563633	0.275153	x	x
LCFREQ	x	x	0.0631856	x	0.0761092	x	x
PR1	1.07092	1.02375	0.764486	0.61189	0.808397	1.13266	1.03073
PU1	0.745385	0.978059	0.593257	0.3847	0.386155	0.983045	0.32899
PR2	0.492518	1.00829	0.767123	0.570138	0.783306	1.06067	1.3532
PU2	0.390636	0.992109	0.543582	0.437515	0.708662	0.927296	0.832438
PR3	0.817955	1.00988	0.821821	0.610065	0.937914	0.813943	0.91783
PU3	0.428619	0.999286	0.395656	0.551239	0.805435	0.137029	0.718249
AP1	1.81029	1.01119	1.80601	1.65075	1.61072	1.10489	2.10553
AP2	2.10174	1.00887	1.76862	1.92646	1.67197	1.19742	1.16102
AP3	2.35248	1.01164	1.74828	1.99236	1.77295	1.23031	1.73837
pseudo-R^2(null) in %	57.41	54.10	52.40	52.29	48.58	48.89	47.46
pseudo-R^2(const) in %	43.82	40.47	41.94	38.22	35.96	32.86	28.30
LR (MNL)	82414	8740	43774	349740	311756	599974	131576
α=0.5%	25.19	23.59	23.59	23.59	23.59	23.59	23.59

TAB 2.03: Overview Estimation Results

The utility function is linear-in-parameters:

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

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

Scale parameters are normalised on the lowest level of the nesting structure to a value of one. For the alternative-specific constants, p- and t-values and the standard deviation of the estimated coefficients see Gelhausen et al. (Gelhausen et al. 2006, pp. 21ff.). TAB 2.04 explains the alternative attributes (Gelhausen et al. 2006, p. 12).

Variable (Abbreviation)	Definition
Access Cost (COST)	Cost in € per Person incl. Parking Fees, Double Trip Length
Access Time (TIME)	Time in Minutes, Double Trip Length
Waiting Time (WAIT)	Inverse of the Daily Frequency
Inverse of the Population Density (INVPD)	Inverse of Residents per km^2
Inverse of the Competition on a Direct Flight Connection(COMP)	Inverse of the Number of Alliances and Independent Airlines
Quality of Terminal Access (AAS)	binary (good/bad)
Existence of a Direct Flight Connection (DIRECT)	binary (good/bad)
Frequency of a Direct Flight Connection (DFREQ)	Number Flights per week
Existence of a Low-Cost Connection (LC)	binary (yes/no)
Frequency of a Low-Cost Connection(LCFREQ)	Number Low-Cost Flights per week
Existence of a Charter Flight Connection (CC)	binary (yes/no)
Frequency of a Charter Flight Connection (CCFREQ)	Number Charter Flights per week

TAB 2.04: Definition of Alternative Attributes

TAB 2.05 displays selected market segment-specific trade-offs between different alternative attributes. The ratio TIME/COST describes the value of access time of an air traveller. For example, one minute access time is worth 37 cent for an air passenger travelling for business purpose to a European destination.

	BRD P	BRD B	EUR S	EUR H	EUR B	INT P	INT B
TIME/COST	0.31	0.75	0.31	0.49	0.37	0.39	0.57
DIRECT/TIME	-280.42	-238.65	-595.00	-387.01	-180.37	-343.52	-81.98
DFREQ/TIME	-0.83	-0.39	-1.71	-1.80	-2.23	x	x
LC/TIME	x	x	-14.13	-65.76	-34.57	x	x
LCFREQ/TIME	x	x	-12.06	x	-11.79	x	x

TAB 2.05: Selected Trade-Offs

The remaining ratios represent the value of a direct flight connection and an additional flight per week, respectively, to the chosen destination in minutes of access time both for all flight types and for low-cost flights separately. TIME is double trip length (to the airport and back), so the values for the last four trade-offs have to be divided by two for the single trip to the airport. A direct flight connection to the chosen destination equals over three hours and an additional flight per week about one minute in access time for European holiday travel. The ratios LC/TIME and LCFREQ/TIME represent the additional effects of low-cost flights.

3. AIRPORT AND ACCESS MODE CHOICE IN THE COLOGNE REGION

3.1 General Overview

Subject of this study is airport and access mode choice in the region of Cologne, which is located in the spatial planning region (SPR) 44 (see FIG 3.01).

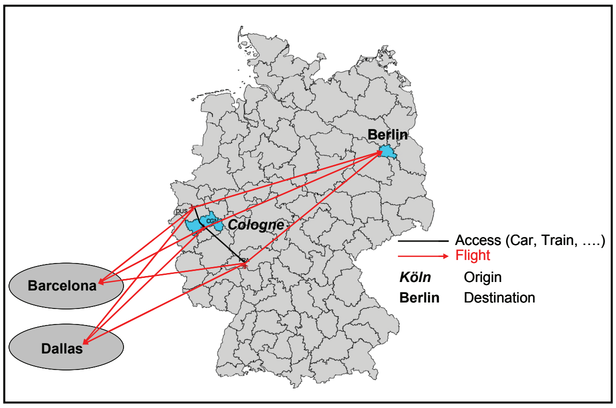

FIG 3.01: Spatial Planning Regions of Germany

SPR 44 serves as an example to analyse the impact of high speed intercity access to airports as it lies in the vicinity of some airports. Air travel demand is mainly served by the airports of Cologne, Düsseldorf and Frankfurt/Main. Three specific destinations were chosen to analyse airport and access mode choice by market segment:

- Berlin for domestic air travel
- Barcelona in Spain for European air travel
- Dallas in the USA for intercontinental air travel

A direct flight exists to Berlin and Barcelona at all three aforementioned airports, but only the airport of Frankfurt/Main serves Dallas via a direct flight.

Low-cost flights play a major role especially in European air travel. Both Cologne airport and Düsseldorf airport offer low-cost flights to Barcelona, however, the weekly flight frequency is higher at Düsseldorf airport than at Cologne airport (28 flights/week vs. 7 flights/week in summer 2005).

The base scenario reflects the status quo with a high speed intercity connection (ICE) between Cologne main station and Frankfurt/Main airport. Travel time by train is about one hour from main station to airport. All three airports are accessible by all seven modes of access.

In the historical scenario, the ICE train is substituted by an intercity access (IC) with a travel time of about two hours, as it was the case before the introduction of the ICE between Cologne main station and Frankfurt/Main airport in 2002.

In a hypothetical scenario, a high speed intercity express of the next generation, like for example the Transrapid, is introduced between Cologne main station and Frankfurt/Main airport. Travel time between main station and airport is 45 minutes and thus 15 minutes less than the ICE. Ticket price and daily frequency between main station and airport are equal to the base scenario.

Subsequently, the dependence between airport market share, ticket price and travel time is analysed based on the previous results.

Necessary data for analysis originates from different sources (Berster et al. 2005; Die Bahn 2005a, b, c; Deutsche Flughäfen 2005; INVERMO 2005; OAG 2005; Taxi 2005; Verkehrsverbünde 2005).

3.2 Base scenario

TAB 3.01 displays the detailed results broken down by airport, access mode and market segment. TAB 3.02 is a summary of the results of TAB 3.01 only arranged by airport and destination. Market segments were weighted by actual travel volume in summer 2005 by the aforementioned three destinations. The demand of the Cologne region to the three aforementioned destinations served by the airports of Cologne, Düsseldorf and Frankfurt/Main lies between 98% and 100% for all market segments, with the only exception of intercontinental private travel to Dallas

	Frankfurt/Main							Düsseldorf							Cologne						
Access	BRD P	BRD B	EUR S	EUR H	EUR B	INT P	INT B	BRD P	BRD B	EUR S	EUR H	EUR B	INT P	INT B	BRD P	BRD B	EUR S	EUR H	EUR B	INT P	INT B
Car	0.02%	0.37%	0.08%	0.09%	0.28%	4.71%	3.49%	0.90%	7.14%	14.77%	2.90%	19.41%	0.94%	3.01%	10.00%	35.17%	3.25%	2.38%	19.19%	2.65%	5.45%
K&R	0.01%	0.02%	0.07%	0.25%	0.05%	9.95%	5.79%	2.54%	1.75%	23.04%	23.52%	8.88%	9.02%	9.35%	37.81%	13.18%	8.80%	27.06%	8.97%	19.78%	20.15%
Rental Car	0.00%	0.02%	0.00%	0.01%	0.02%	0.34%	1.36%	0.02%	0.44%	0.33%	0.32%	1.63%	0.05%	0.61%	0.15%	1.43%	0.09%	0.23%	1.06%	0.09%	0.98%
Taxi	0.00%	0.00%	0.01%	0.04%	0.00%	0.79%	2.38%	0.57%	2.99%	11.83%	8.82%	10.09%	2.49%	6.76%	16.58%	28.02%	5.99%	10.49%	16.61%	6.22%	15.98%
Bus	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	3.70%	0.73%	1.93%	1.52%	0.99%	2.26%	0.72%
UR	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	1.66%	1.23%	14.89%	7.27%	4.35%	1.62%	3.41%	22.06%	4.97%	5.74%	7.12%	3.95%	2.79%	4.62%
Train	0.04%	0.19%	0.11%	0.47%	0.20%	16.28%	11.95%	0.65%	0.53%	7.10%	4.20%	2.66%	0.00%	1.41%	3.28%	1.12%	1.95%	3.34%	1.63%	0.00%	0.64%
Airport	**0.07%**	**0.60%**	**0.27%**	**0.85%**	**0.55%**	**32.07%**	**24.97%**	**6.34%**	**14.07%**	**71.95%**	**47.02%**	**47.03%**	**14.12%**	**24.56%**	**93.59%**	**84.62%**	**27.76%**	**52.13%**	**52.40%**	**33.78%**	**48.54%**

TAB 3.01: Base Scenario

with a share of demand of around 80% served by the three aforementioned airports.

Domestic demand to Berlin is mainly served by the airport of Cologne (94% for private travellers and 85% for business travellers) as a reason of the least access time and access cost of all three airports. Furthermore, it offers the highest number of direct flights to Berlin (132 flights/week in summer 2005). The airports of Cologne, Düsseldorf and Frankfurt/Main nearly serve the whole air travel demand of the Cologne region to Berlin; however, Frankfurt/Main only has a marginal share of less than 1%. The share of Düsseldorf airport is around 6% for private domestic travel and about 14% for domestic business travel, respectively.

	Frankfurt/Main	Düsseldorf	Cologne	∑
Berlin	0.39%	11.03%	88.15%	99.56%
Barcelona	0.66%	52.91%	46.42%	99.99%
Dallas	28.89%	18.80%	40.40%	88.08%

TAB 3.02: Summary of Base Scenario

The air travel demand from the Cologne region to Barcelona is mainly served by Düsseldorf airport, closely followed by Cologne airport. Merged over all market segments, about 53% of air travellers choose Düsseldorf airport for departing, whereas around 46% depart from Cologne airport to Barcelona. Because of its remote location relative to Cologne and a lack of low-cost flights the market share of Frankfurt/Main airport is only marginal again. The remote location cannot be offset by the ICE, as the difference between the shortest access time to Cologne or Düsseldorf airport and Frankfurt/Main airport is at least 37 minutes for the single distance to the airport. The direct flight frequency is considerably better than at Cologne or Düsseldorf airport, though this cannot offset the lack of low-cost flights. In short, the advantages of Cologne and Düsseldorf airport are the shorter access time to the airport and the supply of low-cost flights.

However, in intercontinental air travel to Dallas, the market share of Frankfurt/Main rises sharply, as there is no direct flight connection from Cologne or Düsseldorf airport to the chosen destination. Again, access time is shorter to Cologne or Düsseldorf airport, but this is balanced partly by the better supply of direct flights. Merged over all market segments, Frankfurt/Main airport is chosen by nearly 29% of air passengers travelling to Dallas from the Cologne region, yet about 40% of air travellers take a flight connection with transfer departing from Cologne airport. As Düsseldorf airport offers no direct flight to Dallas and access time is higher than to Cologne airport, it is caught between two stools and only about 19% of air passengers from the Cologne region travelling to Dallas depart from Düsseldorf.

3.3 Historical Scenario without ICE

	Frankfurt/Main							Düsseldorf							Cologne						
Access	**BRD P**	**BRD B**	**EUR S**	**EUR H**	**EUR B**	**INT P**	**INT B**	**BRD P**	**BRD B**	**EUR S**	**EUR H**	**EUR B**	**INT P**	**INT B**	**BRD P**	**BRD B**	**EUR S**	**EUR H**	**EUR B**	**INT P**	**INT B**
Car	0.01%	0.37%	0.07%	0.06%	0.25%	4.98%	2.80%	0.90%	7.15%	14.77%	2.91%	19.43%	1.00%	3.31%	10.00%	35.22%	3.25%	2.38%	19.21%	2.84%	5.99%
K&R	0.01%	0.02%	0.07%	0.17%	0.04%	10.52%	4.63%	2.54%	1.75%	23.05%	23.59%	8.89%	9.67%	10.28%	37.82%	13.20%	8.81%	27.14%	8.98%	21.21%	22.14%
Rental Car	0.00%	0.02%	0.00%	0.01%	0.02%	0.36%	1.09%	0.02%	0.44%	0.33%	0.32%	1.63%	0.06%	0.67%	0.15%	1.43%	0.09%	0.23%	1.06%	0.09%	1.07%
Taxi	0.00%	0.00%	0.00%	0.02%	0.00%	0.83%	1.91%	0.57%	2.99%	11.83%	8.85%	10.10%	2.67%	7.43%	16.58%	28.05%	6.00%	10.53%	16.62%	6.67%	17.57%
Bus	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	3.70%	0.73%	1.93%	1.52%	0.99%	2.43%	0.79%
UR	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	1.66%	1.23%	14.90%	7.29%	4.36%	1.74%	3.75%	22.06%	4.98%	5.74%	7.14%	3.95%	2.99%	5.08%
Train	0.02%	0.07%	0.08%	0.28%	0.16%	10.47%	7.12%	0.65%	0.53%	7.10%	4.22%	2.66%	0.00%	1.55%	3.28%	1.12%	1.95%	3.35%	1.63%	0.00%	0.71%
Airport	**0.04%**	**0.47%**	**0.23%**	**0.54%**	**0.47%**	**27.16%**	**17.55%**	**6.34%**	**14.09%**	**71.99%**	**47.17%**	**47.07%**	**15.14%**	**26.99%**	**93.61%**	**84.72%**	**27.77%**	**52.29%**	**52.44%**	**36.23%**	**53.34%**

TAB 3.03: Historical Scenario without ICE

TAB 3.03 illustrates the detailed results broken down by airport, access mode and market segment. TAB 3.04 summarises the results of TAB 3.03 only arranged by airport and destination. Market segments were again weighted by actual travel volume in summer 2005 to the aforementioned three destinations.

This scenario reflects the situation before the introduction of the ICE between Cologne main station and Frankfurt/Main airport with an IC instead. Between 98% and 100% of the demand of the Cologne region to the three chosen destinations is served by the airports of Cologne, Düsseldorf and Frankfurt/Main airport for nearly all market segments. For the market segment of intercontinental private travel to Dallas, only about 79% of demand is served by the three aforementioned airports.

	Frankfurt/Main	Düsseldorf	Cologne	∑
Berlin	0.30%	11.04%	88.22%	99.56%
Barcelona	0.45%	53.01%	46.53%	99.99%
Dallas	22.85%	20.45%	43.90%	87.20%

TAB 3.04: Summary of Historical Scenario

In relative terms, the losses for Frankfurt/Main airport range between 14% and 41% for the market segments of domestic and European travel to Berlin and Barcelona, respectively. However, these losses occur on a very low level and lie only between 0.3 and 0.8 points represented in absolute terms.

In intercontinental travel to Dallas, Frankfurt/Main airport loses between 15% and 30% in private and business travel, respectively. These values correspond to 4.9 to 7.4 points represented in absolute terms, as demand levels are significantly higher compared to the market segments of domestic and European air travel. There is a slight increase in private modes of access at the airport of Frankfurt/Main in some market segments, but nevertheless, most of the demand is lost to other airports. 70.5% of the lost demand in private intercontinental travel from the Cologne region to Dallas is absorbed by the airports of Cologne or Düsseldorf; however, this value increases to 97.4% in intercontinental travel for business purpose. This case clearly illustrates the high value of access time in the market segments of business travel as already shown by TAB 2.05.

3.4 Transrapid Connection between Cologne Main Station and Frankfurt/Main Airport

TAB 3.05 and TAB 3.06 illustrate the effects of a Transrapid connection between Cologne main station and the airport of Frankfurt/Main. Travel time between main station and airport decrease by 15 minutes to 45 minutes; ticket price and daily frequency are set equal to the ICE of the base scenario.

	Frankfurt/Main						
Access	BRD P	BRD B	EUR S	EUR H	EUR B	INT P	INT B
Car	0.02%	0.37%	0.09%	0.12%	0.30%	4.60%	3.70%
K&R	0.01%	0.02%	0.08%	0.33%	0.05%	9.72%	6.14%
Rental Car	0.00%	0.02%	0.00%	0.01%	0.02%	0.34%	1.45%
Taxi	0.00%	0.00%	0.01%	0.05%	0.00%	0.77%	2.53%
Bus	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
UR	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Train	0.06%	0.30%	0.13%	0.67%	0.24%	18.66%	13.37%
Airport	**0.09%**	**0.71%**	**0.32%**	**1.17%**	**0.61%**	**34.08%**	**27.19%**

	Düsseldorf						
Access	BRD P	BRD B	EUR S	EUR H	EUR B	INT P	INT B
Car	0.90%	7.14%	14.76%	2.89%	19.40%	0.91%	2.92%
K&R	2.54%	1.75%	23.03%	23.44%	8.88%	8.75%	9.08%
Rental Car	0.02%	0.44%	0.33%	0.32%	1.62%	0.05%	0.59%
Taxi	0.57%	2.98%	11.82%	8.79%	10.09%	2.42%	6.56%
Bus	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
UR	1.66%	1.23%	14.89%	7.24%	4.35%	1.57%	3.31%
Train	0.65%	0.53%	7.10%	4.19%	2.66%	0.00%	1.37%
Airport	**6.34%**	**14.06%**	**71.92%**	**46.87%**	**47.00%**	**13.70%**	**23.83%**

	Cologne						
Access	BRD P	BRD B	EUR S	EUR H	EUR B	INT P	INT B
Car	10.00%	35.14%	3.25%	2.37%	19.18%	2.57%	5.29%
K&R	37.80%	13.17%	8.80%	26.97%	8.96%	19.19%	19.55%
Rental Car	0.15%	1.42%	0.09%	0.23%	1.06%	0.08%	0.95%
Taxi	16.58%	27.99%	5.99%	10.46%	16.60%	6.04%	15.51%
Bus	3.70%	0.72%	1.93%	1.51%	0.99%	2.20%	0.70%
UR	22.05%	4.97%	5.74%	7.09%	3.95%	2.71%	4.48%
Train	3.28%	1.12%	1.95%	3.33%	1.63%	0.00%	0.62%
Airport	**93.57%**	**84.52%**	**27.75%**	**51.96%**	**52.37%**	**32.78%**	**47.10%**

TAB 3.05: Scenario with Transrapid

Almost 100% of the demand from the Cologne region to the three chosen destinations is served by the airports of Cologne, Düsseldorf and Frankfurt/Main for all market segments but intercontinental private travel. In this case, about 81% of demand is served by the three aforementioned airports.

	Frankfurt/Main	Düsseldorf	Cologne	Σ
Berlin	0.46%	11.02%	88.08%	99.57%
Barcelona	0.87%	52.81%	46.31%	99.99%
Dallas	31.00%	18.24%	39.20%	88.43%

TAB 3.06: Summary of Scenario with Transrapid

The share of Frankfurt/Main airport increases by 8.9% summed up over all market segments. This conforms to an absolute value of 0.39 points, so that the overall market share of Frankfurt/Main airport to the three chosen destinations is about 4.72%. The low overall value is a result of the low shares of the domestic and European travel segments. Market segment-specific shares are weighted by actual travel volume of summer 2005 as already described above. About 87.5% of the increase in market share is absorbed from the airports of Cologne and Düsseldorf. The largest increases occur in the market segments of intercontinental travel. They range between 2.0 and 2.2 points, whereas the market shares of domestic and European travel only increases by 0.02 to 0.32. Furthermore, there is a considerable increase in train access at Frankfurt/Main airport. The increase in train access lies in a range from 0.01 to 2.38 points, which corresponds to a relative gain from 11.92% to 56.95%. The increase in market share in the important market segments of intercontinental travel are 2.38 points (private travel) and 1.42 points (business travel) in absolute values. This corresponds to a relative gain of 14.60% (private travel) and 11.92% (business travel).

To obtain the same overall market share of Frankfurt/Main airport as in the base scenario, an increase in the ticket price (one-way) of 7.10 € to 42.40 € is possible. If air travellers are divided into private and business segments only, the ticket price can rise by 5.91 € for private passengers and 8.60 € for business passengers. This large difference in willingness-to-pay is due to the higher time value of business travellers compared to private passengers. These findings result from TAB 2.05 and to obtain aggregated results, market segments were weighted by airport choice for the destinations Berlin, Barcelona and Dallas in summer 2005. The results of TAB 2.05 hold generally.

3.5 Airport Choice and Access Quality

In this chapter airport choice dependent on train access is analysed in a more general way on the basis of the example Frankfurt/Main airport. The chosen market segment is intercontinental private travel to Dallas as it has the highest travel volume of the examined cases from the point of view of Frankfurt/Main airport.

The two main factors in this analysis which are considered here are ticket price and travel time. Daily frequency is held constant equal to the value of the base scenario and equals 23 connections from Cologne main station to Frankfurt/Main airport.

FIG 3.02 illustrates the choice of Frankfurt/Main airport to Dallas in intercontinental travel dependent on ticket price and travel time, both one-way, over a reasonable range. The three scenarios are indicated by a dark point. Travel time includes about 25 minutes of access to Cologne main station.

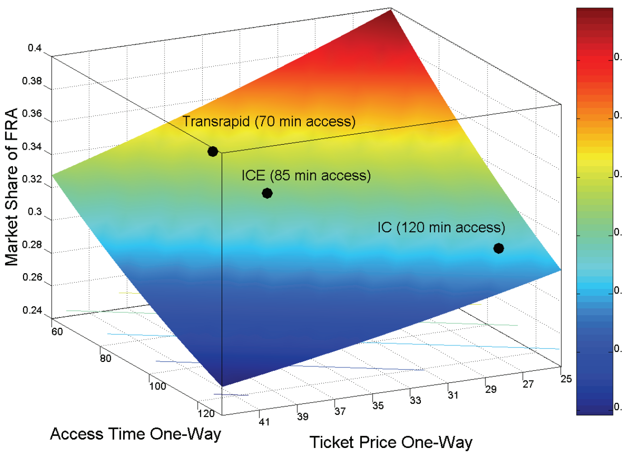

FIG 3.02: Airport Choice and Access Quality

Private air passengers travelling to intercontinental destinations are considerably more ticket price-sensitive on a low level of access time, i.e. only a slight decrease in ticket price in necessary to gain a comparatively sharp increase in airport market share. In contrast, a much greater decrease in ticket price is necessary to trigger the same increase in airport market share on a higher level of access time to the airport.

The same relationship holds the other way around: Air travellers are clearly more access-time sensitive on low a level of ticket price, whereas the gain in access time has to be larger on a higher level of ticket price to receive the same increase in airport market share. Even though the utility function is linear, some form of nonlinear or asymmetric behaviour can be observed. The IC-scenario is efficient, i.e. it is better in respect to at least one attribute compared to the other scenarios. This is the reason why it is not really far behind. The high access time of the IC scenario is at least partly offset by the low ticket price.

Ultimately, air traveller's preferences determine the best alternative, in this case the Transrapid scenario.

FIG 3.03 represents a cut along the “Access Time One-Way” axis through the Transrapid and ICE scenario of FIG 3.02. The ticket price is fixed at 35.30 € and is equal to the base scenario and the Transrapid scenario. The base scenario with an ICE between Cologne main station and Frankfurt/Main airport and the Transrapid scenario are highlighted in FIG 3.03.

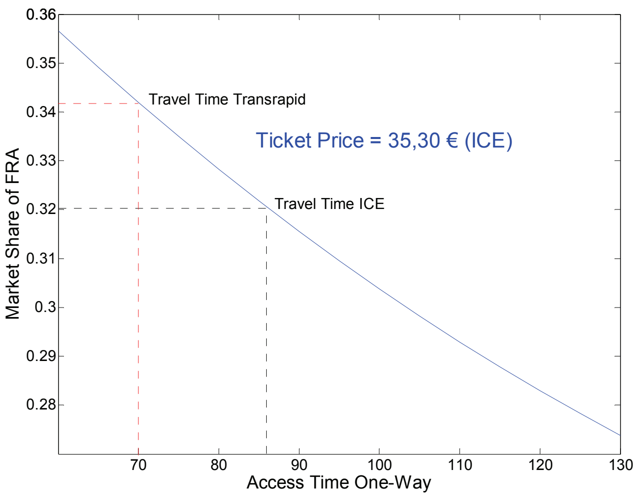

FIG 3.03: Access Time vs. Market Share

The decrease in travel time by train of about 15 minutes causes an increase in market share of about 2 points. 15 minutes access time equal 5.87 € access cost, both measured one-way.

FIG 3.04 displays a cut along the “Ticket Price One-Way” axis through the Transrapid scenario of FIG 3.02. The average access time of 70 minutes from the Cologne region to Frankfurt/Main airport is equal to the Transrapid scenario. Again, the reduced access time by train of 70 minutes to the airport causes a 2 point increase of market share in intercontinental private travel to Dallas. The other way around, the ticket price could rise to 41.17 € without reducing the market share to the chosen destination compared to the base scenario, i.e. an ICE between Cologne main station and Frankfurt/Main airport.

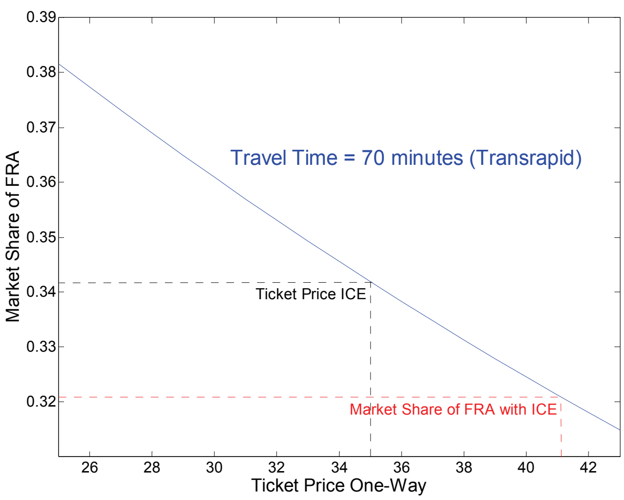

FIG 3.04: Ticket Price vs. Market Share

FIG 3.03 and FIG 3.04 highlight a specific example of FIG 3.02 and illustrate the value of time from two different points of view. They represent an application of the TIME/COST ratio in TAB 2.05 to a specific application case.

3.6 Airport Choice and Network Density

So far, only access quality, which is mainly determined by access time, access cost and daily frequency, to the airport of Frankfurt/Main was varied. Better access quality results in a higher market share especially to intercontinental destinations, which are served by direct flights only from Frankfurt/Main airport compared to the airports of Cologne and Düsseldorf. The competitive advantages of Cologne and Düsseldorf airport are their proximity to the trip origin (from the point of view of the Cologne region) and their supply of direct and low-cost flights to domestic and European destinations. The airports of Cologne and Düsseldorf are first choice for air travellers from the Cologne region to domestic or European destinations under these circumstances. For travelling to intercontinental destinations, many air passengers are willing to travel to Frankfurt/Main airport to take a direct flight to their chosen destination instead of taking a flight connection with transfer at Cologne or Düsseldorf airport. But what are the impacts of intercontinental direct flights at Cologne or Düsseldorf airport on choice behaviour? Obviously, a considerably share of air travellers might changes their departure airport in favour of Cologne or Düsseldorf airport, respectively. TAB 3.07 shows the impact of an intercontinental direct flight connection from Düsseldorf airport to Dallas on airport and access mode choice in the Cologne region. This scenario is equal to the base scenario except for the intercontinental direct flight connection at Düsseldorf airport.

	Frankfurt/Main		**Düsseldorf**		**Cologne**	
Access	**INT P**	**INT B**	**INT P**	**INT B**	**INT P**	**INT B**
Car	2.17%	3.00%	4.11%	4.49%	1.22%	4.68%
K&R	4.60%	4.97%	39.53%	13.95%	9.13%	17.32%
Rental Car	0.16%	1.17%	0.23%	0.91%	0.04%	0.84%
Taxi	0.36%	2.05%	10.93%	10.08%	2.87%	13.74%
Bus	0.00%	0.00%	0.00%	0.00%	1.04%	0.62%
UR	0.00%	0.00%	5.54%	4.05%	1.29%	3.97%
Train	7.52%	10.27%	0.00%	1.67%	0.00%	0.55%
Airport	**14.81%**	**21.46%**	**60.34%**	**35.15%**	**15.60%**	**41.72%**

TAB 3.07: Intercontinental Direct Flight from Düsseldorf

About 98% of the demand of intercontinental business travellers and 91% of the demand of intercontinental private travellers is served by the airports of Cologne, Düsseldorf and Frankfurt/Main.

The market share of Düsseldorf in intercontinental air travel to Dallas increases by 46.2 points in private travel and 10.6 points in business travel. This equals a relative increase of 327.4% and 43.2%, respectively. 86.0% (76.7% in private travel and 97.4% in business travel) of the increase in market share is absorbed from the airports of Cologne and Frankfurt/Main.

The high increase in market share is due to the high time value of a direct flight connection as already illustrated by the ratio DIRECT/TIME in TAB 2.05. A direct flight connection equals around three hours access time one-way for intercontinental air passengers travelling for private purpose, but only 41 minutes for business travellers. This is the reason why the increase in market share of Düsseldorf airport is by far sharper for private intercontinental travel. Private travellers in intercontinental travel place more emphasis on a direct flight connection than on access time compared to intercontinental business travellers. This is also true for the other market segments; however, the difference is not so distinct.

4. SUMMARY AND CONCLUSIONS

In this paper the impact of high speed intercity train access on airport choice behaviour is analysed exemplarily by means of airport and access mode choice in the region of Cologne. Analysis is conducted on the basis of a nested logit-model, which is applicable to an arbitrary number of airports and any airport/access mode combination. In this study 22 German airports with seven potential modes of access per airport are analysed.

The train connection between Cologne central station and Frankfurt/Main airport is a matter of particular interest. Three scenarios are studied:

- Intercity (IC) connection with about two hours travel time between main station and airport
- Intercity Express (ICE) connection with about one hour travel time between main station and airport
- Transrapid connection with about 45 minutes travel time between main station and airport

Furthermore, a better supply of intercontinental direct flights at Düsseldorf airport is simulated to study whether an improved supply structure at a different airport close to Cologne overcasts any improvements in access quality.

The study shows the importance of both access quality and the supply of direct and low-cost flights for airport choice. Many possible departure airports are nearby in a decentralised airport environment like Germany and high speed intercity access moves airports even closer to the trip origin of the air traveller leading to an enlargement of the catchment area and an increase of the market share of an airport.

However, if the airport is too far-off, the effects of high speed access are only small, as there is at least one airport with similar supply of flights closer to the trip origin of the air traveller. This is a result of the decentralised airport environment in Germany with a comparatively high number of airports and enhances competition between airports.

Nevertheless, there is a large potential for increasing the catchment area of an airport by high speed intercity access, which is rather limited by economic considerations than by technological reasons, as the marginal costs of catchment area enlargement steadily rise.

The other main determinant of airport choice is the supply of direct and low-cost flights. The time value of a direct flight connection is large, especially for private air travellers against what business travellers put more emphasis on access time compared to private travellers. The time value of a direct flight connection ranges from 2.5 to 5 hours for the single trip to the airport. This value lies between 42 minutes and two hours for business travellers. If Düsseldorf airport offers direct flights to intercontinental destinations just as Frankfurt/Main airport, the effects on airport choice in the Cologne region are very large.

The question whether access quality outweighs the supply of direct flights or the other way around in relation to airport choice cannot be answered universally valid and depends on specific circumstances, which have to be analysed as the case arises.

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