Long-Term Developments of the German Main Airport Network: An Integrated Planning Approach

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Demand for air transportation in Germany experienced a significant growth after the reunification in 1990. Current forecasts indicate that demand is likely to continue growing in the following two decades, and this may lead to capacity shortage of the airport infrastructures if no action is taken. The purpose of the study described in this paper is to determine the long term capacity needs of the German airport infrastructure in order to deal with future demand. This is accomplished by determining which airports should receive additional capacity and where should new airports be built.

Differently to other published studies, here the expansion decisions are analyzed in the framework of an airport network using an optimization model. The model looks to a set of metropolitan areas, served by airports or not, and determines the set of expansion actions to apply to the metropolitan areas in order to cope with future demand in the best possible way, while complying with a given budget.

The optimization model is a mixed-integer and nonlinear, being virtually impossible to handle through exact solution methods. Therefore, a heuristic algorithm was developed to solve the model. The algorithm is two-level: the upper-level component of the algorithm generates tentative expansion actions to apply to the airport network (candidate solutions); the lower-level component assesses the candidate solutions after simulating the equilibrium traffic flows and travel costs in the airport network. A greedy-type algorithm was developed to generate the candidate expansion actions to apply to the airport network, whereas the computation of the equilibrium in the network is made through the method of successive averages.

In Germany, the federal government is responsible for coordinating the expansion projects from a superregional and intermodal perspective. It is thus accountable for ensuring that the capacity of the airport infrastructures meets the projected levels of

demand, and for guaranteeing that the necessary long-distance transport links are provided by connecting the airports with the rail and road networks. Hence, this study takes into account the impact of expansion decisions on travel demand, and on the competition/ complementarity between travel modes, namely between air, rail, and road transport.

The study focused on the 14 metropolitan areas of Germany, which contain the 17 international airports of the country. These airports handle almost 90% of the country's air traffic flows. In order to capture the behavior of the regional passenger demand around the multi-airport systems (passengers may be willing to use secondary airports in order to avoid the congested primary airports), the secondary airports serving the metropolitan areas were also considered (it was admitted that for an airport to be considered part of a multi-airport system, it should be within one hour's drive of one of the international airports). The list of the metropolitan areas and airports considered is given in Table 1.

Table 1: Set of airports and metropolitan areas considered in the study

Metropolitan Area	Airport code	Airport name	International
Hamburg	HAM	Hamburg-Fuhlsbüttel airport	X
Hamburg	LBC	Lübeck Blankensee airport	
Hannover	HAJ	Hannover-Langenhagen airport	X
Bremen	BRE	Bremen airport	X
Düsseldorf	DUS	Düsseldorf International airport	X
Düsseldorf	CGN	Köln/Bonn airport	X
Düsseldorf	DTM	Dortmund airport	X
Düsseldorf	NRN	Weeze (Niederrhein) airport	
Frankfurt	FRA	Frankfurt am Main airport	X
Frankfurt	HHN	Frankfurt-Hahn airport	
Stuttgart	STR	Stuttgart airport	X
Stuttgart	FKB	Baden-Baden/Karlsruhe airport	
Nürnberg	NUE	Nürnberg airport	X
München	MUC	München airport	X
Berlin	TXL	Berlin Tegel "Otto Lilienthal" airport	X
Berlin	SXF	Berlin-Schönefeld airport	X
Saarbrücken	SCN	Saarbrücken airport	X
Saarbruecken	ZQW	Zweibrücken airport	
Münster	FMO	Münster Osnabrück International airport	X
Leipzig	LEJ	Leipzig/Halle airport	X
Dresden	DRS	Dresden airport	X
Erfurt	ERF	Erfurt-Weimar airport	X

The design reference used in the study for planning purposes was a peak day of 2030. The possible expansion actions to apply to the metropolitan areas were defined after analyzing in the possibility of improving runways and adding new runways to the existing airports, as runways are generally the most constraining elements of airport systems.

According to the study, if the existing airport network remains unchanged, seven metropolitan areas would not have enough capacity to serve all demand, and two other metropolitan areas would present severe congestion problems. Yet, traffic would increase by about 14% relatively to 2009. If a budget of €50 billion is provided for the expansion of the airport network, the study points out that the capacity of seven metropolitan areas should be increased through the expansion of nine airports (Figure 1 and Table 2). With these improvements in the network, traffic would increase by about 47% relatively to the do-nothing situation. With a budget of €100 billion, the airport network should be improved through the expansion of five additional airports, and traffic would increase by about 53% (Figure 2 and Table 3). Finally, using a €150 billion budget, four other airports should also be improved and a new airport with three runways should be built in Düsseldorf (Figure 3 and Table 4). Traffic would increase 62% relatively to the do-nothing situation.

Although the study developed provides good indications regarding the evolution of the German airport network, it can be improved with respect to a number of issues. This includes, in particular, the specification of the travel demand function, a deeper analysis of the possible expansion actions applicable to the airports, and the consideration of different scenarios regarding the evolution of air transport (including aircraft and ATM systems). These issues will be the scope of our future research in this topic.

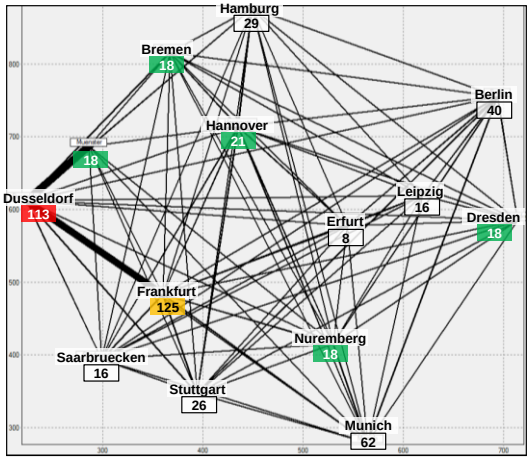

Figure 1: Airport network in 2030 for a budget of €50x10^3 M

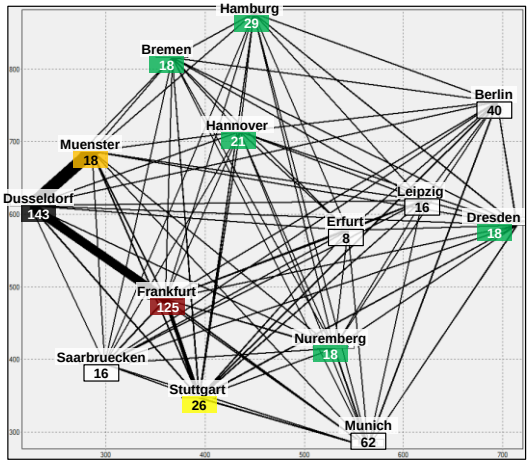

Figure 2: Airport network in 2030 for a budget of €100x103 M

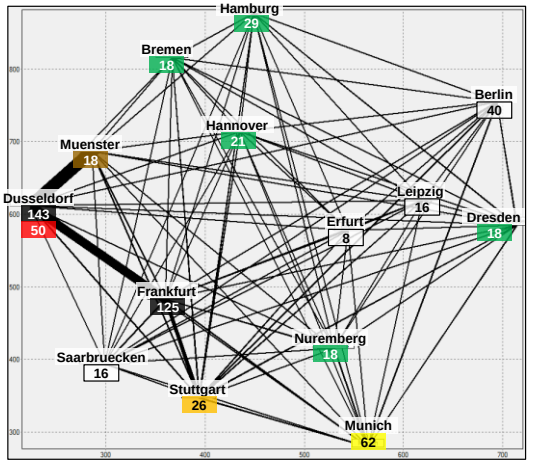

Figure 3: Airport network in 2030 for a budget of €150x103 M

Table 2: Traffic and costs for the airports in 2030 for a budget of €50M

Center	Capacity	Traffic	Ratio	Tax
Hamburg	29	26	89%	0.00
Hannover	21	15	73%	0.00
Bremen	18	9	50%	0.00
Düsseldorf	113	113	100%	1.07
Frankfurt	125	114	92%	0.00
Stuttgart	26	26	100%	2.66
Nürnberg	18	14	75%	0.00
München	62	50	80%	0.00
Berlin	40	25	62%	0.00
Saarbrücken	16	6	34%	0.00
Muenster	18	18	100%	6.40
Leipzig	16	11	67%	0.00
Dresden	18	12	67%	0.00
Erfurt	8	6	76%	0.00

Table 3: Traffic and costs for the airports in 2030 for a budget of €100x103 M

Center	Capacity	Traffic	Ratio	Tax
Hamburg	39	27	69%	0.00
Hannover	21	15	70%	0.00
Bremen	18	8	46%	0.00
Düsseldorf	143	143	100%	0.00
Frankfurt	155	127	82%	0.00
Stuttgart	46	37	79%	0.00
Nürnberg	18	14	75%	0.00
München	62	50	81%	0.00
Berlin	40	25	62%	0.00
Saarbrücken	16	6	35%	0.00
Muenster	38	35	91%	0.00
Leipzig	16	11	68%	0.00
Dresden	18	12	68%	0.00
Erfurt	8	6	76%	0.00

Table 4: Traffic and costs for the airports in 2030 for a budget of €200x10^3 M

Center	Capacity	Traffic	Ratio	Tax
Hamburg	39	27	69%	0.00
Hannover	21	15	69%	0.00
Bremen	18	8	45%	0.00
Düsseldorf	193	160	83%	0.00
Frankfurt	165	132	80%	0.00
Stuttgart	56	38	68%	0.00
Nürnberg	18	14	75%	0.00
München	72	50	70%	0.00
Berlin	40	25	63%	0.00
Saarbrücken	16	6	35%	0.00
Muenster	58	41	70%	0.00
Leipzig	16	11	68%	0.00
Dresden	18	12	68%	0.00
Erfurt	8	6	76%	0.00