2016 ATRS WORLD CONFERENCE, Rhodes, Greece, June 23 – 26, 2016

A NEW MODEL OF LONG TERM FORECASTING AIR PASSENGER DEMAND AND THE NUMBER OF AIR TRANSPORT MOVEMENTS OF GERMANY

Marc C. Gelhausen, Peter Berster, Dieter Wilken
German Aerospace Center (DLR)
Institute of Air Transport and airport Research
51147 Cologne, Germany
Phone: +49 2003 6012567
E-Mail: Dieter.Wilken@dlr.de

ABSTRACT

The DLR has developed and applied a “classical” model of forecasting the total number of air passengers and aircraft movements and the cargo volume at German airports for many years. The model follows the traditional approach of forecasting the trip generation, spatial distribution and assignment to routes and aircraft movements. In recent years it has been found more and more difficult to update and verify the model because of lack of specific data. We have therefore developed a more versatile model, which directly forecasts the total number of air passengers and of air transport movements at the ensemble of German airports. The forecast functions are co-integrated structural regression models which have been econometrically estimated taking into account time series data of 1992 to 2014. The paper describes the model approaches and discusses advantages and disadvantages of the classical and new model approach.

KEYWORDS

Air transport demand and supply forecasting; passenger and cargo demand and air transport movement model; classical four step model, co-integrated structural regression model.

CORRESPONDING AUTHOR: Dieter Wilken, DLR

1. Introduction

It is generally understood that forecasts are estimates which should be based as far as possible on causal relationships, with input data, hypotheses, and methods stated and described in a retrievable way for those who use them. In contrast to prophecies, forecasts yield "if-then"-results, the validity of which is typically limited because of scarcity of data, lack of methodological quality, and uncertainty of occurrence of influencing factors and premises. In spite of the conditionality of results there is a general demand for prethinking future alternatives in order to realise one future, in line with Saint-Exupery, who stated that one should not want to foresee the future but make the future feasible.

Air transport politics and infrastructure planning, research and development of transport technologies need estimates of future demand for transport services and their changes in consequence of alternative developments of the air transport environment. As long as States pursue a demand oriented planning of transport infrastructure by following established political objectives, especially that of free choice of the mode, having solid expectations of that demand is a prerequisite for realising such transport policy. In addition, for long range planning of a transport system it is useful to know the future transport requirements for different socio-economic scenarios on the one hand and for transport strategic options on the other.

The forecasting task is not make such statements about the development and volume of transport demand which participants of the planning process (i.e. the public affected by projects) have to believe or not, but rather to elaborate on relationships, i.e. functions or chains of arguments, between demand and influencing factors and to evaluate them and the significance of results.

The fact that more and more political decisions of investment projects are redebated in legal proceedings shows the growing interest of the public in knowing about the arguments which have led to these project decisions. The public tends to question more and more the validity of forecasts and takes a skeptical attitude towards forecasting and "forecast experts".

There is no unique solution to the problem of how to abridge the discrepancy between the risk and uncertainty of forecasting and the necessity of making forecasts available for planning purposes (forecast dilemma). One possibility for reducing the weight of the task is to regard forecasting as a continuous effort and thus take account of newest developments of data and methodology. The DLR has developed some time ago a “classical” four step model to forecast passenger demand and flight volume at German airports, which will be described in the following. Although this model cannot be regarded as obsolete, various circumstances have led to the need to develop a new model which is more versatile and better responding to nowadays forecast questions than the former one. A main factor has been the lack of specific data needed for the updating demand model segments. The new model which relies more on statistical data available will be described in the second part, to be followed by a discussion of the benefits and drawbacks of both models.

2. Forecast Hypotheses

The development of air transport demand depends on many factors, the forecast of which is partly risky or requires a complex procedure itself. For understanding and not misinterpreting the transport forecast results all input factors forecast should be stated. Since these factors are partly interrelated it must be ascertained that their forecasts are internally consistent. Especially those factors should be stated which influence the transport variable to a great deal and at the same time are controversial in their estimated values, like for instance the future intensity of airline competition and the effects of capacity shortages.

In the DLR-forecasts the known structures of the relationships between demand and demand factors are transcribed into the future. Among the factors of great influence is on the most aggregate level the economic output of the study area, as for instance expressed by the Gross Domestic Product (GDP). Directly interrelated with the GDP is the private consumption and the foreign trade, two input variables, which are useful indicators of the demand for private and border-crossing business air travel. As can be seen in Fig. 1, the development of air traffic, both measured by revenue passenger-kms (RPKs) and freight ton-kms (FTKs) is similar to the growth of the global GDP over a long period of time. Major crises like the terror attacks in September 2011 and the world recession in 2008/09 had a negative impact on air transport growth, however, air transport in general recovered fast and grew with an average of around 5 % growth rate per year.

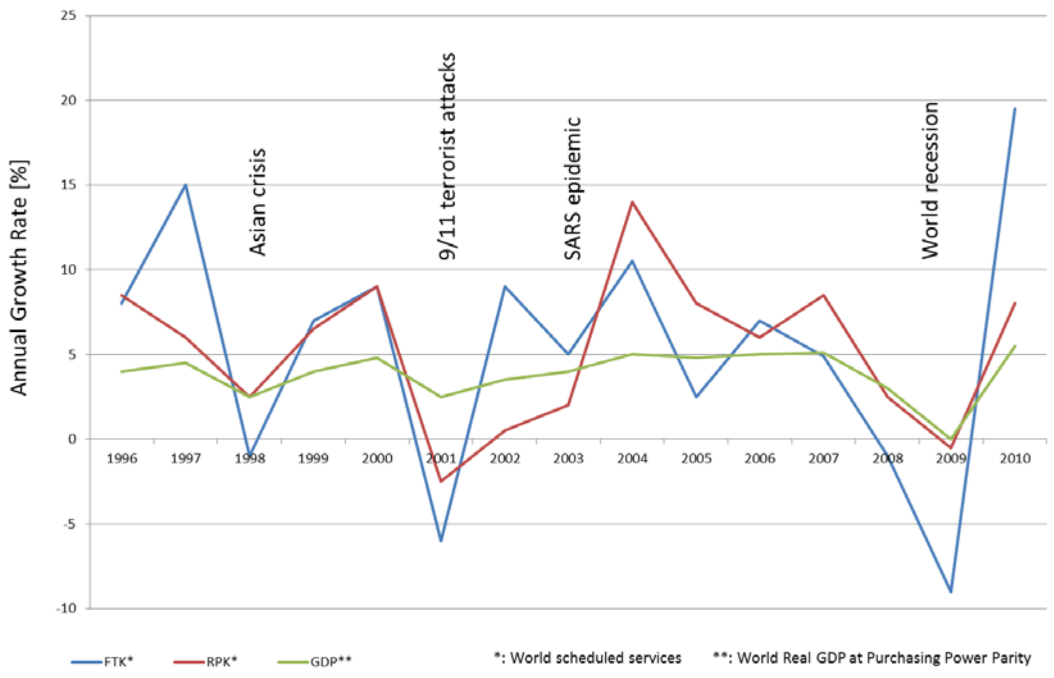

Fig. 1: The Development of Global Gross Domestic Product (GDP) and Air Traffic (Passengers and Freight), Source: ICAO (2013).

The past development of air travel, especially in the European charter and low-cost-carrier market and the domestic US market, has shown that there exists a rather complex relationship between the demand and supply with strong feedback effects of supply features like the price of travelling on demand. For the purpose of using this relationship for forecasting one has to break it up into several straight forward relationships, which are dealt with consecutively. In the first phase of the forecast it is assumed that there will be no capacity restraint in the transport system, so that the forecast demand - estimated solely in relation to demand factors - can be handled with. In fact the models described, deal solely with the demand – demand factor relationship, whereby the demand factors may include supply characteristics like prices. In following phases one must reexamine this working hypothesis by forecasting system capacities, comparing traffic volumes with capacities and - in the case of shortcomings - introduce transport strategies and re-estimate the traffic and/or the demand, and repeat the sequence.

In general, the hypotheses to be stated belong to four categories:

- General political conditions

- Socio-demographic and economic conditions

- Conditions as set by transportation politics (i.e. investment programs of competing modes)

- Travel behavior.

Only relatively few hypotheses are quantifiable and entering the demand functions as factor variables; most others are qualitative in nature, and as such limit the validity range of forecast results. Usually we assume that the general political conditions will not change. Influencing factors from the socio-demographic and economic scenery which are often used as variables in demand models are the size and structure of the population and the GDP. In long range forecasts traffic infrastructure variants are often described by demand influencing characteristics like price and travel time differences. Travel behavior is supposed to be reflected by the formulation of the demand model, i.e. by trip generation rates in category analysis matrices.

3. The Four-Step Passenger Demand and Flight Movement Model

The objective of the former DLR-forecasts has been to estimate passenger flows and flight volumes at the international airports in Germany for a time span of 10 to 20 years ahead. Since the amount and structure of the demand for air transport services is dependent on socio-economic and other factors (with the quality of the supply having a feedback influence on the demand) it was regarded essential to first estimate the future demand (passengers, freight) and subsequently on that basis the volume of flight movements (Wilken, 1996).

The main steps of the air transport forecast are:

- **Demand Forecast**:
  1. Demand generation by market segments of trip purpose (business, holiday, and other trips) and of traffic region (domestic, European, and Intercontinental),
     results: trip generations (travel volumes of zones), travel flows
  2. Assignment to types of service (scheduled, charter service)
  3. Assignment to airports of the study region
  4. Seasonal assignments (peak hour, annual demand)
  5. Assignment to routes; result: link volumes (passengers)

- **Flight Movement Forecast**:
  6. Estimation of passenger flights; variables: load factor, type mix, frequency;
     iterative calculations: extreme value and plausible solutions;
     result: link volumes (ATM's)
  7. Seasonable assignments: (peak hour, year)
  8. Estimation of other flights: freight, other commercial and non-commercial

The method used reflects a compromise between the requirements as set by the forecast results to be elaborated and the restrictions as given by the empirical base. Of the 8 phases shown, the first, the demand analysis and forecast, and the sixth, the derivation of flight movements, are the main phases of the study, however, for calculating airport and route loadings, several intermediate steps are to be carried out (phases 2 to 5 and 7 to 8).

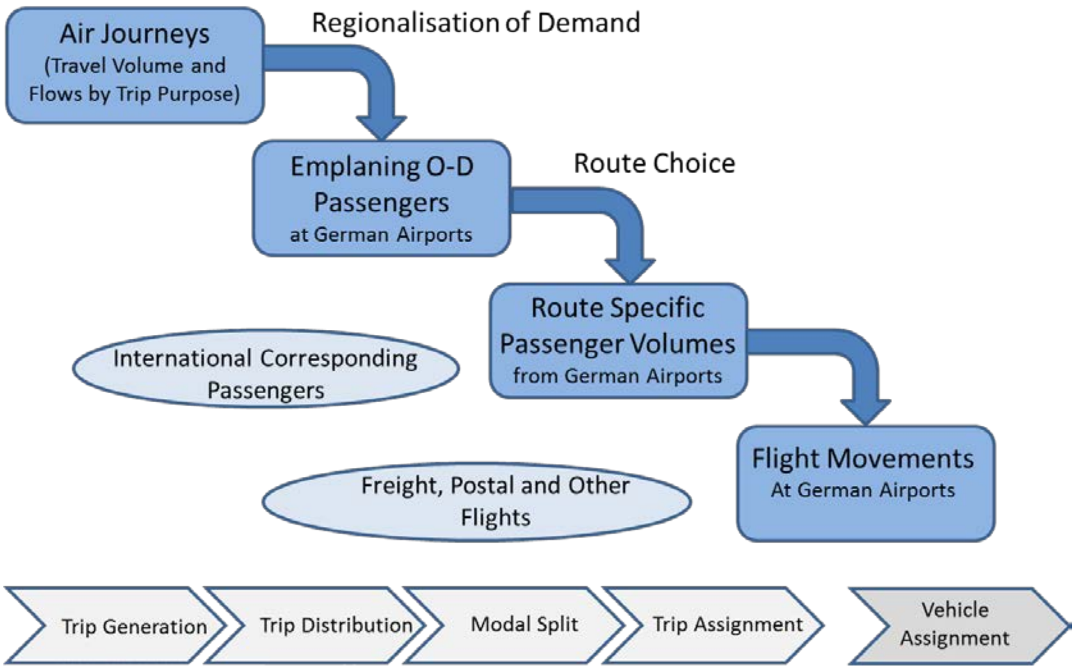

Fig. 2: Classical Four-Step Model of DLR Passenger Demand Forecast of Germany

As can be seen in Fig. 2 the DLR-Model follows with the phases of trip generation, trip distribution, modal split and trip assignment the traditional four-step algorithm of models used for simulating and forecasting traffic (Manheim, 1979). This methodological approach had been developed originally for modelling urban and regional traffic, however, has also been extended to long distance travel (Wilken, 1977).

The air journey of a passenger as the ensemble of all trips from origin O to the destination D has been defined as the unit of demand that is subject of forecasting. In the first phase the number of journeys generated in and attracted to Germany as the study region is forecast by using different approaches depending on the trip purpose (see Chapter 3.1). This model part is by far the most complex one; it forms the basis for all following parts.

The trip distribution includes the step of spatially partitioning the trip volume of Germany to the originating airports in Germany and destination zones outside Germany. The result of this top down approach is a matrix of O-D flows between German airports and between these and international regions, and in summa the airport specific passenger volumes.

The modelling of the modal split refers in the DLR Model to the derivation of air journeys out of the total flow of holiday travelers on a given O-D pair. The holiday travel volume and flows have been estimated for all traffic modes, because holiday travelers choose between modes on many short to medium distance routes, quite in contrast to business travelers, who decide on the mode when determining the destination on the basis to minimizing travel time. In addition, in the case of substantial improvements of train travel times, air travel flows primarily on short distance routes have been reduced by a substitution factor which has been derived from a comparison of before and after travel times by rail.

The fourth model step is the trip assignment by which the O-D flows are assigned to the routes served by direct flights. The summing up of flows at an airport results in the number passengers emplaned at this airport. The trip assignment requires a forecast of route structures of travel flows – not all passengers fly on direct flights – and of the realization of new routes served in future, which again has an impact on the route structure. This phase includes thus a first feed-back process of the hypothetically assumed direct services and the size of the travel volume, which has to be above a route specific threshold value.

The last model step is the vehicle assignment by which route specific travel volumes are converted to the number of flights. In iterative calculations with varying values of the load factor, seat capacity per flight and flight frequency “reasonable” outcomes of flight numbers are estimated. The iterations are guided by typical values of the influencing factors as they have been found in route specific analyses and reports about aircraft acquisition strategies of airlines. If the forecast is to estimate the total traffic volumes at airports, additional forecasts have to be made regarding the development of freighter flights, taxi, business and general aviation.

3.1 Demand Segments

Reflecting factors which cause people to travel, i.e. making holidays, meeting friends and relatives, seeing places, and selling goods and services, the demand has been analysed and forecast by trip purpose group. Since statistical data of passenger travel do not differentiate flows by purpose (but by type of service) one has to rely on special surveys, which in the past have normally been carried out by airlines for market research purposes. These trip purpose specific data have been and are still regarded as an essential base for forecasting because travel intensities, developments, and spatial structures vary significantly with trip purpose. Unfortunately, airlines find more and more that these surveys are too expensive and rely today more on booking data (MIDT data) which are produced by various sources such as Sabre Airport Data Intelligence (Sabre ADI). These booking data are used for yield management and network planning purposes.

In addition to trip purpose classes, market regions were identified which differ by modal substitution potential and destination attractiveness. On short haul traffic relations the air passenger flow is only part of the total demand between the two regions, which should be taken into account by forecasting both the total flow and the modal split. For forecasting domestic air transportation in Germany and international travel flows with neighboring countries this has not yet been possible because of lack of comparable passenger flow data for rail and road travel. On theoretical grounds such an approach is superior to a unimodal model, the calibration of a multimodal model for the air mode, however, remains a difficult task as long as air travel accounts for only a very small portion of the total travel.

Analyses of the trip purposes of air transport demand of Germany, carried out over several years, have shown that the structure is composed of only a few segments the relative size of which has changed only slowly over time (Berster et al, 2010, Hepting et al., 2011). In a high level differentiation of demand segments we may distinguish between two major groups, which are business and holiday travellers, as can be seen in Fig. 3. Short stay personal travellers form the third group which has been much smaller than the other groups. While in former years, in particular before 2002, when Low Cost Carriers began with services in the German market, the segment of short stay personal travellers was only in the order of less than 4 %, this group has grown in response of the low cost services to about 13 % in 2014. At the same time, the domestic demand has somewhat lost in importance, the portion went down from about 16 % in 1991 to 11 % in 2014.

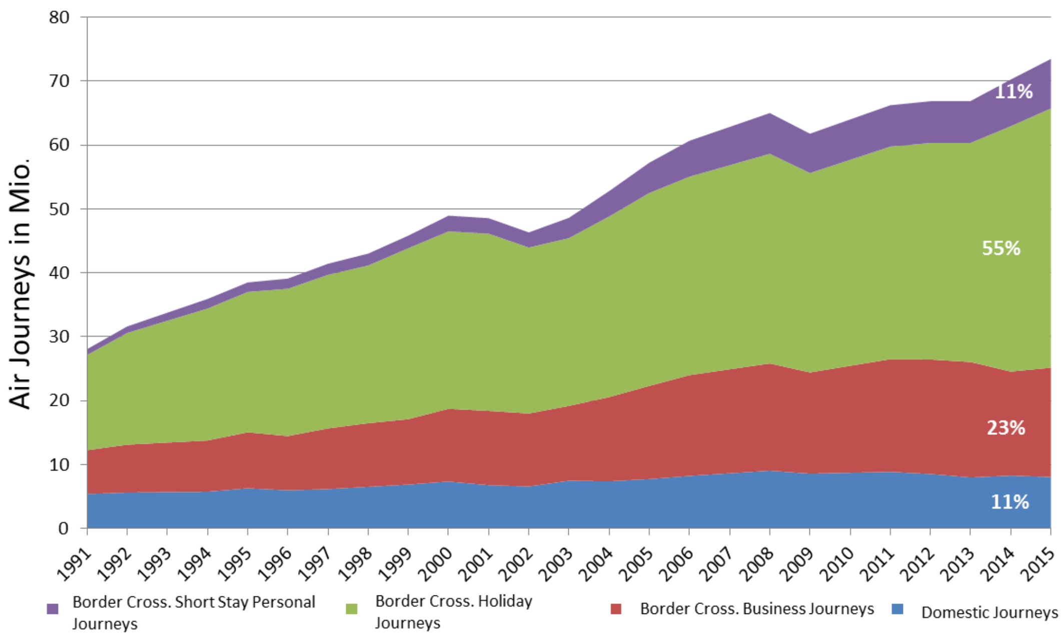

Fig. 3: Development of Air Passenger Demand of Germany 1991 – 2015 by Trip Purpose

In the year 2014, the trip purpose structure of air transport demand in Germany was as follows:

- Business travel: ca. 31 %
- Holiday travel: ca. 56 %
- Short stay personal travel: ca. 13 %

Travellers going on holidays formed and still form thus the biggest group of air transport demand, followed by business travellers. Business travellers use the plane both for domestic trips as well as for international trips. Nearly 70 % of all domestic trips are business trips, so that in total over 30 % of all air journeys is made for business reasons.

The trip purpose structure varies with each travel route (or origin – destination link). Short haul domestic travel is made up primarily by business travellers (68 %), whereas in inter-continental travel holiday travellers form the biggest part, with around 75 %. The type of route may therefore be regarded as a criterion of segmenting the travel market. In addition, travel influencing factors vary spatially with the traffic originating in or attracted by a region. They are to be found partly in Germany for the travel originating there, and they are correlated with the country or region of origin in the case of travel of foreigners coming to visit Germany.

The following demand segments have been defined on the basis of criteria like trip purpose, trip origin and type of travel route (or relation), after having analysed the availability of data relevant for forecasting:

- Domestic air journeys
- International business journeys by air
- International holiday journeys
- International short stay personal journeys by air.

Domestic origin to destination (O-D) journeys by air (not counting passengers corresponding at German airports) form a separate segment, which consists mainly of business travellers and competes with high speed ground modes. In the past, for a long time 85 % of domestic air passengers used the air transport mode for business reasons, however, caused by low air fares of low cost carriers, demand for short stay personal trips has been generated recently, so that the portion by business travellers decreased to about 68 %. Never the less, the domestic air travel market is still characterized by business trip making. The domestic segment forms, quite in contrast to the border crossing air travel, only a small part of the total air transport demand. In the year 2014, almost 90 % of all air journeys in O-D travel of Germany had either trip origin or destination in a foreign country, German air transport is thus primarily internationally oriented.

As mentioned, the strongest segment of air travel demand is the group of border crossing holiday travellers, forming about 55 % of the total O-D demand. For reasons of forming rather homogenous groups for the forecast, this segment has been subdivided further into the group of travellers with trip origin in Germany (primarily German travellers) and those with trip destination in Germany (mainly foreigners visiting Germany), the former segment again into age specific groups, since the age of travellers plays a major role in the decision process of holiday trip making. The origin segment is compared with the destination segment relatively small. Germany is not a destination country strongly frequented by foreign holiday travellers in air transport. Over 85 % of all holiday journeys by air are generated in Germany, less than 15 % are foreigners coming to Germany for making holidays here.

Nearly a quarter of total air travel demand is border crossing business travel. For the purpose of forecasting, this segment has been subdivided first into origin travel (mainly by Germans) and destination travel (mainly by foreigners) and consequently into groups by service and industry branch. This allows reflecting influential factors which act branch specifically. In contrast to holiday travel, border crossing business travel is not dominated by travellers originating in Germany but rather – varying by branch – balanced between inbound and outbound travel.

For a long time, just 4 % of the total passenger demand for air transport of Germany belonged to the group of short stay personal travel to and from international destinations. Since about 2002, this portion has almost tripled due to the emergence of low fare services of low cost carriers, however, short stay personal travel forms with 13% still a small segment in relation to business and holiday travel.

3.2 Segment Specific Approach of Forecasting Demand

The methodological approaches of forecasting the demand segments differ primarily in that those related to business travel are of econometric nature and those of private travel demand are less functional but more extrapolations of trip characteristics, like trip intensity or frequency, by travel group. The groups refer to the demand either originating in Germany or with a destination in Germany on the one hand and to subgroups of the population, especially age specific groups, on the other hand. In Fig. 4 we have summarized the model approaches by market segment, the structure of which is added in the bottom line.

	Air Transport Demand Segments of Germany					
	Domestic Air Journeys	Border Crossing Air Journeys				
		Business Journeys		Private Purpose Journeys		
		Originating Travel	Attracted Travel	Originating Holiday Travel	Attracted Holiday Travel	Private Short Stay Travel
Forecast Model Approach	Dominated by business travel demand: Trip generation dependant on macro-economic productivity (GDP per employede person)	Branches of producing industry: Trip generation dependant on export rates; service sector: branch specific trend extra-polations	Ratio of originating and attracted travel demand almost constant over time; branch specific extra-polation of this ratio	Forecast of total holiday trip generation and modal split analysis; age group specific trend extra-polation of trip intensity, fre-quency and de-stination choice	Trend extra-polation of observed developments	Trend extra-polation of observed developments; special consideration of low cost carrier travel
Influencing Variables	Economic development, employment	Foreign trade, employment		Population, age structure, private income		
General Forecast Hypotheses	Continuous development of society and economy in Germany and world wide; further liberalisation and globalistion of transport; no capacity restraints in the air transport system; no basic change in the consumption behaviour.					
Structure 2014	11	12	11	47	8	11

Fig. 4: Segment Specific Model Approaches of Forecasting Air Passenger Demand of Germany

For the **domestic air transport demand**, consisting mainly of business travellers, an econometric model has been chosen, which has been verified empirically for a long period of time (Pak et al., 2005) The function yields the propensity to fly, as expressed in the number of journeys in domestic O-D travel per person employed, in relation to the macro-economic productivity, expressed in the gross domestic product (GDP) per person employed. This relationship is explained by the fact that the factors causing and influencing the trip making in domestic air travel for business purposes can be derived directly from the complex acquisition, production and distribution processes of the economy of Germany. There exists thus a mutual relationship between a change in the macro-economic production, which is again related to a change in the spatial division of labour and distribution processes, and the demand for business travel in total and the specific demand for business travel by air. To exclude changes in the GDP growth which are caused by a change in the work force or by business cycles, the function between demand and GDP relates the trip generation rate with the productivity, thus including the number of employed persons in the variables.

The **demand for international business travel** by air results from economic activities of industry and services, including the international division of labour, and from international relations of public and private institutions. Business travel is as such a complementary demand for taking up, maintaining and intensifying business relations, the objective of which is commerce of goods and services. Since the border crossing business travel is thus a necessary prerequisite for realising foreign trade a methodological need has been seen for incorporating foreign trade as an explanatory variable in the forecast function.

A direct forecast of the total border crossing business travel seems to be a suboptimal approach since we can assume that the relationship between foreign trade and business travel demand varies by sector of economy, and in the case of service sectors, such a relationship may exist only indirectly or not at all. Unfortunately, demand data by sector of economy do not exist so that a sector specific approach cannot be pursued for the time being. Instead and similarly to the domestic demand, a functional relationship has been formulated between the trip generation rate of the demand originating in Germany and the export productivity, whereby both rates are related to the labour force in order to avoid the influence of variations in the export caused by a change in the number of persons employed. Regarding the travel demand generated abroad, with destinations in Germany, it has been observed that the portions of either origin or destination demand in the total demand of border crossing business travel varied only marginally over time. The demand of visiting business travellers was thus forecasted in relation to the demand originating in Germany.

For forecasting the business travel demand by air input data are needed which describe the future development of the German GDP, foreign trade and the number of person employed in Germany. These data have been available so far.

In contrast to business travel the forecast of **holiday travel by air** is based on a multimodal model, since these journeys are to be considered as integral part of holiday tourism. The multimodal approach concentrates on the trip generation in Germany, that is the holiday trips of the German population, which account for 85 % of all holiday trips. For the incoming holiday trips long time series of data are available, which have been used to directly extrapolate the travel volume of this market segment. Based on different data sources in holiday tourism of Germany and of incoming holiday travel to Germany the following subgroups have been identified:

- Holiday trips originating in the Study Region

  -- Main holiday trips made by the adult population in German households
  -- Second and third holiday trips of that population
  -- Holiday trips made by children (until the age of 14 years)

- Holiday trips made by foreigners (i.e. foreign employed persons) living in the Study Region

- Holiday trips originating abroad (with destination in the Study Area)

For forecasting the trip generation of the segments originating in Germany travel propensities (travellers per capita) and frequency rates (trips per traveller) were derived from time series data and extrapolated for each subgroup, further subdivided by age group. The main holiday trips and the additional holiday trips have then been distributed per age group to destination zones. The distribution was guided by time series data available for each group. Subsequently, the holiday flows from Germany to international destination were modally split into air transport and all other modes. The decision to travel and the modal choice were thus modeled in relation to the age, and so indirectly to the period of life, position in family and profession, and a growing immobility in old age groups. The choice of mode is also influenced by these factors and in addition by the type of holiday destination area. This category analysis has the advantage of transparency of decisions, beginning with the decision to make a journey to the point of choosing the mode of traveling. However, detailed data are required over a long period of time, so that travel behaviour changes, based on the aging process, can be accounted for in forecasting the demand for holiday travel. Furthermore, the age-group approach allows explicitly considering changes in the demographic structure of the German population in future.

Holiday trips of children have been forecast in relation to the trips of age-groups of parents. For the holiday trips of foreigners living in Germany time series data have been available, which allowed to extrapolate them to estimate future trip volumes of this sub group.

Direct extrapolations of time series data have been applied also for the smallest segment, the **private short stay trips** in international travel. This market segment has grown faster than the other segments, since the low cost carriers have generated traffic in particular in this travel group. When the demand model was further developed and applied in the years 2005/06 the low cost carrier traffic in Germany was still young and developing rather fast. This means that the time series were too short in order to account properly for the generation effect of low cost traveling. An application of the time series today would clearly show both the amount of travel generation due to the introduction of low cost services and the saturation tendency which has been observed more recently, meaning that a time series based extrapolation would yield rather plausible results now. It should be noted, however, that the forecast of induced demand as a consequence of substantial improvements of air services, in this case significant price reductions, has always been a rather difficult task. On reason being that the data do not reveal whether the newly generated demand stems from modal shifts from other modes or comes from non-transport activities.

The result of the demand forecast are trip purpose specific passenger flows which have been assigned to scheduled and charter services. Whereas business travellers rely predominantly on scheduled services, private travellers use both service types, depending primarily on the destination. The assignment was based on statistical time series data of flows by service type and took into account airline policy of providing scheduled and charter services.

The assignment of the country specific flows to the airports in the Study Region is not a straightforward exercise, since a forecast method of determining the true origins and destinations of passengers and their airport choice behaviour in relation to the journey destination had not yet been developed at the time when the model was developed. A somewhat mechanistic approach was used therefore, by which the time series of airport shares of the country specific flows were extrapolated. These curves normally represent stable functions, with exception of those traffic relations where direct services had been introduced. Since new services will be introduced on some relations in the future as well those country flows will have to be assigned to airports in an iterative procedure, in a first phase according to the "without new direct services"-function and then after having checked the suitability of introducing direct services on the basis of minimum demand levels, according to the "with direct services"-function.

On a growing number of European transport corridors high speed trains will introduced before the target year of the forecast. Modal substitution by rail had to be taken into account therefor on all those city-pairs which will be affected by the new train services, like on the cross-channel link. With estimates of airport-airport flows in Germany and airport-country flows in border-crossing travel as intermediate forecast results modal change functions can be applied which determine the portion of air travellers being attracted by the fast trains in relation to the new rail-air time difference.

The next step is the assigning of O-D flows to the routes served. One would assume that in air transportation, being the fastest and most expensive way of travelling this could be simulated by applying a minimum path algorithm since not many alternative routes except the most direct one would be used by passengers. This hypothesis is certainly correct for charter services and short range O-D relations, but it is not for medium and long range relations in scheduled travel. On anyone relation between an airport of the Study Region and a destination region typically around 5 alternative routes must be considered for assigning O-D flows, with intercontinental relations having many more routes. The split between passengers flying on direct services and those on all indirect services can be simulated by using well defined empirical functions.

Assigning all O-D flows of the flow matrix to the routes served yields the passenger traffic volumes on the links of the network under consideration. These volumes serve as a base for estimating the number of flights on these links and, in summing up over all links of an airport, the number of flight movements at that airport.

3.3 Flight Movement Forecast

Based on the future passenger volume on each network link the number of flights corresponding to the demand can be estimated by functionally relating them to each other by means of the key variables:

- Frequency of services (number of flights per time unit),
- Load factor (number of passengers per number of seats offered)
- Distribution of aircraft types by seat capacity class offered on anyone link type.

The procedure of estimating the number of flights requires the specification of lower and upper values of these variables for each link and service type for determining the margin of plausible forecast solutions, which again have to be searched for through an iterative approach by inserting variable values which lie in between the extreme values. The variables are interrelated by the following sequence of functions:

$$SC_c = (PAX_c) / (LF_p)$$

$$\downarrow$$

$$SC_c = (SCF_c)\,(Fr_p) \longrightarrow FR_c = (SC_c) / (SCF_c)$$

$$\downarrow$$

$$SCF_c = (SC_c) / (FR_p) \longrightarrow FR_c$$

With:	Lfmin	$<$ LF_p (LF_c) $<$	LFmax
	Frmin	$<$ FR_p (FR_c) $<$	FRmax
	SCFmin	$<$ SCF_p (SCF_c) $<$	SCFmax

Where:

PAX	= Passenger volume per network link as a result of the demand forecast (input)
SC	= Seat capacity to be offered on the link
LF	= Average load factor (%)
SCF	= Average seat capacity per flight
FR	= Frequency, number of flights to be offered on the link
c,p	= indicate calculated and postulated values

In the first step the number of seats to be offered on a link is calculated by dividing the value of the passenger volume (as estimated by the demand forecast) by an estimated value of the average load factor.

The seat capacity on a link is not only determined by the passenger volume and the load factor but also by the frequency and the average number of seats offered per flight. The frequency variable is both an input and, after an iterative analysis of different values within the link and service specific margins, the output variable.

For the derivation of plausible results of the future flight volume (FRc) on each link, it is obligatory to go through a sequence of calculations of employing different but internally consistent pairs of FR and SCF values. These values which enter the above given functions are average values of distributions which have to be estimated as well for arriving at a final estimation. It is felt that this procedure is feasible only if link specific time series data of the key variables have been available and analysed accordingly. The extrapolation of these data and estimation of future values depends on airline strategies of offering services and the competitive environment of airlines; these strategies have to be formulated as forecast variants, for instance as a status quo or a liberalisation alternative.

It should be noted that the forecast method as described does not yield one and only one solution. For a demand level given different flight movement volumes are conceivable, depending on the assumed size distribution of the aircraft to be operated.

The flight movements in scheduled and charter traffic are only one part of all operations in the airspace and at airports; freight, military, and general aviation flights contribute as well to the overall traffic volume. Freight flights are typically small in number as compared with passenger flights, they are, however, difficult to forecast since the freight data base is rather weak. This is even more so the case with military flights. General aviation may contribute at many airports substantially to the total volume of take-offs and landings.

4. The New Direct Demand and Flight Model

This model is based upon the fact, that many socio-economic time series and traffic time series as well are non-stationary because of a stochastic trend (e.g. Nelson & Plosser, 1982). Fig. 5 shows time series data for GDP growth in the European Union, flight volume growth, passenger volume growth and passengers per flight growth at German airports, which are used in the model. There is clearly a trend observable, as indicated by the regression lines. These time series are typically integrated of order 1 (I(1)), i.e. differencing once produces stationary results. However, by differencing we lose information about levels, therefore we have chosen a cointegration approach. Generally, the ordinary least squares (OLS) method does not apply for non-stationary variables and performing OLS in this case yields a so-called spurious regression. However, there is one exception: If variables are cointegrated, so that the stochastic trends of the variables cancel out, OLS produces valid results (Engle & Granger, 1987). Cointegration means that there is a long-term equilibrium between non-stationary variables, and they cannot move independently from each other in the long run. However, these variables can deviate from their long-term equilibrium in the short-term, but there will be an adjustment process, so that these variables tend towards their long run equilibrium, if they are cointegrated. Short-term deviations from the equilibrium and the adjustment process are the objective of error correction models (ECM). However, for our purposes, i.e. medium and long-term air traffic forecasts, we will focus on cointegration. For model development, we employ the Engle-Granger testing procedure (Enders, 2004): After pretesting the variables for their order of integration, we estimate the long-run relationship via OLS regression. Then we perform an (augmented) Dickey-Fuller (ADF) test (Dickey & Fuller, 1979; MacKinnon, 1991) on the residuals of the regression. Basically, the variables are cointegrated, if the residuals are white noise.

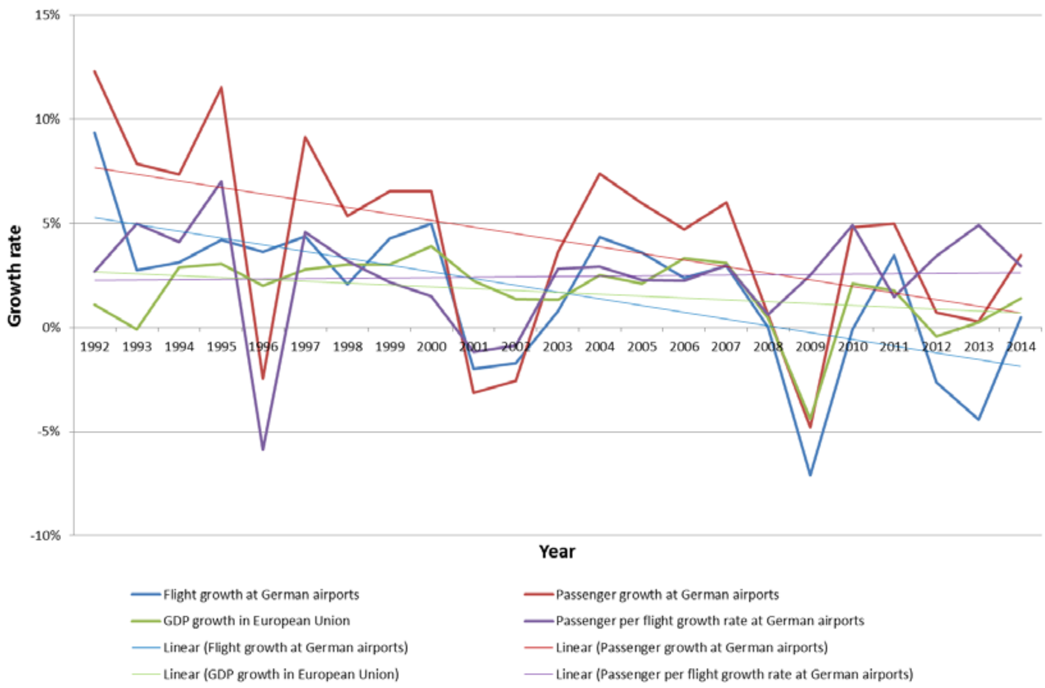

Fig. 5: Time Series Data of GDP Growth in the European Union, Flight Volume Growth, Passenger Volume Growth and Passengers per Flight Growth at German Airports (WDI, 2015; Statistisches Bundesamt, 2015)

Table 1 shows the estimation results of the passenger model and Fig. 6 shows a comparison between actual values and an ex-post forecast. The model has an R^2 of 97.3% and residuals series has an ADF statistic of -6.68. The dependent variable is the annual passenger growth rate at German airports in %. We have categorised the independent variables as follows:

- The intercept variable, highlighted in black,
- Primary explanatory variables, highlighted in blue, and
- Secondary explanatory variables, highlighted in green.

The intercept term is a rather technical necessity of a standard regression model. However, the differentiation between primary and secondary explanatory variables deserves special attention. The two primary explanatory variables are the GDP growth rate in the European Union and the growth rate of passengers per flight. The GDP growth rate variable helps to model the demand side of the air transport market. The GDP growth rate of the European Union performs best in terms of model statistics, because the majority of flights from German airports are to European destinations. We also tested global and German GDP growth rates, however the results were not as good. The growth rate of passengers per flight serves as a variable to model the supply side of the air transport market: Increasing loading factors or aircraft size raises economies of scale. This is an effect that can be observed at German airports since the low-cost carrier development has gained momentum: While passenger per flight grew on average by 2.09% per year from 1992 until 2003, the rate increased to 2.84% per year for the period from 2004 to 2014. The average value for the time period of 1992 to 2014 is 2.45% per year. Primary explanatory variables are aimed at the future and they have a direct effect on the forecast of the dependent variable. E.g., a GDP growth rate forecast for the European Union influences the forecast of annual passenger growth rate at German airports directly. The elasticity between those two variables is expressed by the regression coefficient that has been estimated and describes the long-run relationship between those two variables (amongst others).

	Coefficients	*Standard error*	*t Stat*	*p-value*
Intercept	-0.01029747	0.004065447	-2.53292334	0.022961765
GDP growth rate in European Union (in %)	1.33864893	0.119364016	11.2148449	1.08373E-08
Growth rate of passengers per flight (in %)	0.88189283	0.086731874	10.1680361	4.01135E-08
German Unity	0.38154884	0.037471924	10.182259	3.93795E-08
9/11 Attacks (2001 & 2002)	-0.0361058	0.007640279	-4.72571692	0.00027065
Post 9/11 & SARS (2004 & 2005)	0.02138957	0.007003294	3.05421484	0.008034097
Post Sub-Prime Crisis (2011 & 2012)	0.02369593	0.007791007	3.04144679	0.008246059
Arab Spring in Egypt (2012 & 2013)	-0.03286561	0.008291649	-3.96370023	0.001248201

Table 1: Estimation Results of the Passenger Model

On the other hand secondary explanatory variables are aimed at the past in first place: They account for positive or negative shocks, that have occurred in the past and that have not been captured fully by the primary explanatory variables. To qualify for such a variable, the shock has to significant in a statistical meaning, as illustrated by Table 1. All explanatory variables are highly significant (p-value < 0.1%). Thereby, secondary explanatory variables support an unbiased and efficient estimation of the primary explanatory variables and the identification of a cointegration relationship. With the exception of the German Unity variable, all secondary explanatory variables are dummy variables and relevant years are specified in brackets. The German Unity variable is defined as (1/(Forecast Years - 1990))^2, i.e. the effect is barely noticeable after the year 2000 and it is really significant only for the years 1992 and 1993.

However, the secondary explanatory variables serve another “soft” purpose: The approach chosen allows for the quantification of size of positive or negative shocks that are not included in the primary explanatory variables (“partial effects”). E.g., the 9/11 Attacks resulted in a decreased GDP growth rate in the European Union that reduced in a lower passenger growth rate at German airports for the years 2001 and 2002. However, the strong decrease of the passenger growth rate (-3.1% in 2001 and -2.6% in 2002) was far beyond the “GDP-effect”: According to the model results there was an excess effect of -3.6% for each of the years 2001 and 2002 due to the 9/11 Attacks and adjusted for the GDP- (and passengers per flight-) effect. On the other hand, the Lufthansa fleet renewal (1996) and the Sub-Prime Crisis (2008 & 2009) were fully explained by the primary explanatory variables, i.e. the growth rate of passengers per flight and the GDP growth rate in the European Union, respectively.

By quantifying such shocks we are able to compare and categorise them. This is a first step in making empirically sound conjectures about future shocks. This is especially difficult for short- and medium-term forecasts of say up to five years. However, for long-term forecasts average values are useful: For the period of 1992 to 2014 the average value of the shocks was -0.14%.

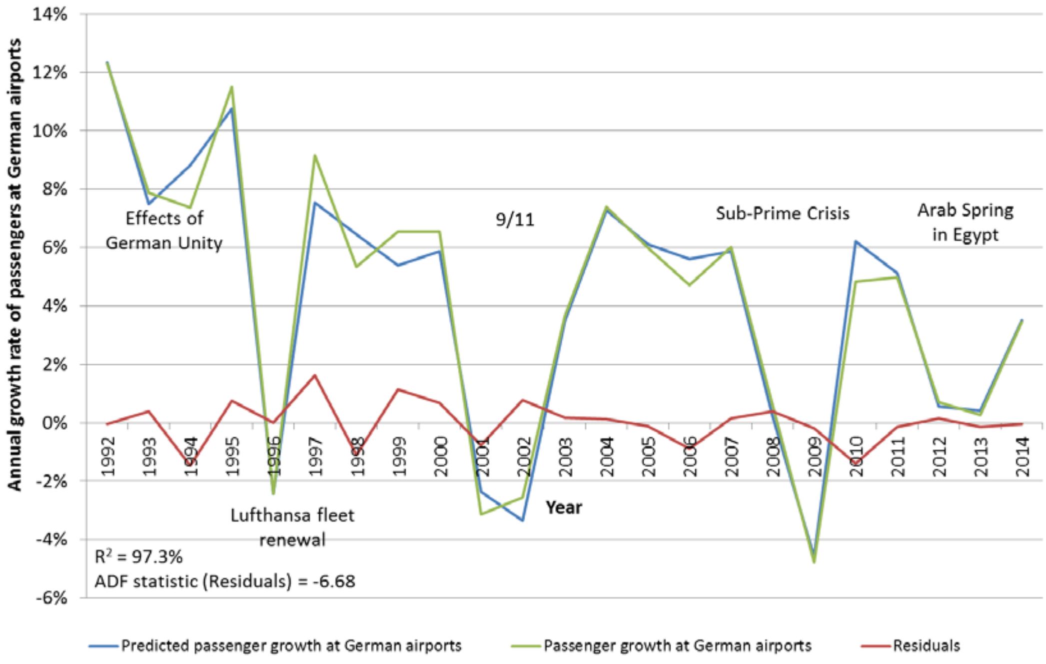

Fig. 6: Actual time series and ex-post forecast of the passenger model

Table 2 shows the estimation results of the flight model and Fig. 7 shows a comparison between actual values and an ex-post forecast. The model has an R2 of 100% and residuals series has and ADF statistic of -4.59. Primary explanatory variables are the passenger growth rate and the growth rate of passengers per flight. Secondary explanatory variable is the 9/11 Attacks, however, while being highly significant the effect is barely noticeable.

	Coefficients	*Standard error*	*t Stat*	*p-value*
Intercept	0.00101816	0.000158633	6.41832508	3.73633E-06
Passenger growth rate (in %)	0.96938002	0.002660059	364.420474	5.41996E-38
Growth rate of passengers per flight (in %)	-0.99995844	0.004546426	-219.943852	7.93493E-34
9/11 Attacks (2001 & 2002)	-0.00208076	0.000372562	-5.58498967	2.18981E-05

Table 2: Estimation results of the flight model

The aforementioned reasoning applies to the flight model as well; nevertheless, there are some remarks: The R^2 of 100% applies if we put the true passenger growth rate into the model. If we have only a forecast value, R^2 is less. If we combine the passenger and the flight model, we arrive at an R^2 of 97.3%. However, this results in an interesting conclusion: If we take a closer look at the estimated coefficient we can basically conclude:

Flight volume growth rate = Passenger volume growth rate – Growth rate of passengers per flight

Further research has shown that this even holds at airport level, if the airport does not have a relative high share of air freight and freight integrators. In this case, the aforementioned equation only holds approximately.

Fig. 7: Actual Time Series and Ex-post Forecast of the Flight Model

5. Discussion and Conclusions

The **four step passenger demand and flight movement model** (Chapter 3) consists of eight consecutive phases, of which the demand generation phase as the most important one lays the base for all following steps. The complete application of the model yields for each forecast year rather detailed forecast results, such as:

- Passenger volumes of the study area (i. e. Germany) by trip purpose
- OD-Passenger flows between study area zones (in Germany) and foreign zones
- Passenger volumes on routes served by scheduled and charter flights
- Passenger volumes of airports of study area (Germany)
- Passenger flight volumes in scheduled and charter traffic by route
- Passenger flight volumes of airports of study area (Germany)
- Flight volumes of other traffic segments, i. e. freighter flights, of airports of study area (Germany)

It may well be that certain airport, airline or network related problems and planning questions do not require forecasts of the whole set of output variables as given by the model. On the other hand, traffic forecasts of single airports for example are often incomplete if they do not consider the interactions with other airports. The four step model offers obviously the greatest advantage if policy and planning questions around long term developments of air traffic in national networks have to be answered.

Estimating the output variables as described for future years requires the existence of time series data of socio-demographic and economic data of the study area and other world regions and of passenger, cargo and flight data of the domestic and border crossing network. In addition, forecasts of the socio-demographic and economic data have to be available; and the underlying hypotheses of these input forecasts have to be consistent with the air traffic forecast. While air traffic supply data become more and more available as official or industry data, trip purpose specific demand data are less and less available. These data are to be collected in passenger surveys, the cost of which airlines and airports are less interested to bear, since other market research data are commonly available like for instance booking data in form of so called Market Information Data Tapes (MIDT) of several providers. Equally, cargo data in sufficient granularity regarding commodity group and OD-relation are not easily available and often not complete. The updating of the model becomes thus a costly and cumbersome task, aside from the fact, that running the model and interpreting intermediate and final results requires efforts and intimate knowledge of air traffic developments, too. One way out of this resource problem is the elaboration of specific models that concentrate on certain forecast questions without regarding the full spectrum of potential output variables. An answer is the newly developed direct demand and flight model as described in Chapter 4.

The **direct demand and flight model** allows to directly forecast the total passenger and flight volume at the ensemble of airports in Germany without going through the chain of intermediate structural variables like OD-passengers at airports or on network links and assignments of OD-passengers to routes served. As a consequence, forecasts of airport and route specific passenger and flight volumes are not subject of this approach at the time being. It is conceivable, however, that the direct demand model may be successfully estimated for single airports or regions with some airports, which are not dependent on airports outside the study region.

The model output, that is the number of passengers, includes emplaning and deplaning passengers including transferring passengers. The forecast variables are defined in the model growth rates per year. The model of the passenger volume of Germany is based on GDP growth of Europe, the development the average number of passengers per flight as a variable describing the supply side of air transportation, and a variables representing special events like terror attacks in 2001 or the world economic crisis in 2008/09 et al. The flight forecast model includes the result of the passenger model, the development of passengers per flight and a correction factor for special events, in this case the 9/11 Attacks. In order to apply the model forecasts of these variables serve as input data. Since the model is based on time series data the forecasts of these variables should not reflect futures which are not compatible with a status-quo development. This condition which restricts the predictive ability of the model is more or less prevailing in all model applications.

The forecast functions are co-integrated structural regression models which have been econometrically estimated taking into account time series data of 1992 to 2014. The regression functions describe therefore long term equilibrium relationships between the dependent and explaining variables. First applications of the model have shown minimum deviations between observed and estimated volumes. A methodological strength may thus be its temporal stability because of the reliance of time series analyses, whereas the classical approach has a stronger base in cross-sectional analyses.

As has been stated, one reason for developing the direct demand model has been the scarcity of demand data as they are required for the four step model, in particular trip purpose specific data in detailed granularity. Booking data like MIDT data are replacing more and more trip purpose data of passengers. If this trend continues we have to assume that the quality of models will be negatively impacted. Nevertheless, forecasts based on sound models will be needed in future as well. Direct demand and flight models will be developed further and give answers to special forecast problems, like the future overall passenger volume of a country or another study region. If long term strategic forecasts of air transport developments in whole networks are needed, classical four step models in combination with scenario analyses will be required. It may well be that a greater part of forecast functions of the four step model will be made up by direct demand and supply models. Direct demand models should also if possible be based on individual passenger data gained in surveys especially set up for model estimates and combined with time series models.

6. References

Berster, P., Maier, W., Pabst, H., Wilken, D. (2010), „*Daten zur räumlichen Struktur der Luftverkehrsnachfrage, Ergebnisse der Fluggastbefragung 2008*“. Internal Document, DLR.

Dickey, D.A. und W.A. Fuller (1979), “Distribution of the Estimators for Autoregressive Time Series with a Unit Root”, *Journal of the American Statistical Association*, 74(366), pp. 427–431.

Enders, W. (2004), *Applied Econometric Time Series*. Wiley & Sons, 2004.

Engle, Robert F.; Granger, Clive W. J. (1987), “Co-integration and error correction: Representation, estimation and testing”, *Econometrica*, 55(2), pp.251–276.

Hepting, M., Pak, H., Wilken, D. (2011), “The Demand for Air Transport and Consequences for the Airports of Hamburg and Rostock” in: Kronenberg, T., Kuckshinrichs, W. (Ed.), *Demography and Infrastructure, National and Regional Aspects of Demographic Change*, pp.111- 129, Springer, Dordrecht, 2011.

Manheim, M. (1979), *Fundamentals of Transportation Systems Analysis*, The MIT Press, Cambridge, USA, 1979.

MacKinnon, J. G. (1991), “Critical values for cointegration tests” in: *Long-Run Economic Relationships: Readings in Cointegration*, ed. R. F. Engle and C. W. J. Granger. Oxford University Press, 1999.

Nelson, C. R.; Plosser, C. R. (1982). “Trends and random walks in macroeconomic time series”, *Journal of Monetary Economics*, 10(2), pp.139-162.

Pak, H., Claßen, A., Hepting, M., Wilken, D., 2005. „Zur zukünftigen Luftverkehrsnachfrage in Deutschland“. 20. Verkehrswissenschaftliche Tage, Technische Universität Dresden: *Grenzenloser Verkehr in einem grenzenlosen Europa*, 2005.

Statistisches Bundesamt (2015), *Luftverkehrsstatistik*. Statistisches Bundesamt, Wiesbaden, 2015.

Wilken, D. (1977), “European Passenger Travel Demand, Analysis and Strategy Responsive Forecast”, in: Transport decisions in an age of uncertainty, Proceedings of the Third World Conference on Transport Research, Rotterdam, pp.211-221, Martinus Nijhoff, The Hague – Boston, 1977.

Wilken, D. (1996), “Forecasting Demand and Aircraft Movements in Scheduled and Charter Air Traffic in Germany”. ECAC: Airport and Air Traffic Systems Interface (APATSI), Forecasting Seminar, London, 1996.

The World Bank (2015), *World Development Indicators*, Washington D.C., 2015.