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The *Journal of Air Transport Studies* (JATS – ISSN: 1791-6771) is a peer reviewed journal aiming at publishing high quality research related to air transport. JATS is interested in publishing papers primarily focusing on economics, geography, policymaking, management, marketing, operations, technology, logistics/supply chain management and modelling.

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- Forsyth P. (2002a), 'Privatization and Regulation of Australian and New Zealand Airports', *Journal of Air Transport Management*, 8, 19-28.
- Papatheodorou, A. (2008) The Impact of Civil Aviation Regimes on Leisure Market. In Graham, A., Papatheodorou, A. and Forsyth, P. (ed) *Aviation and Tourism: Implications for Leisure Travel*, Aldershot: Ashgate, 49-57.
- Skycontrol (2007) *easyJet welcomes European Commission's decision to limit PSO abuse in Italy*. 23rd April. Available from: http://www.skycontrol.net/airlines/easyjet-welcomes-european-commissions-decision-to-limit-pso-abuse-in-italy/ (accessed on 22/08/2008).

Conference Reports should be between 1,000 and 1,500 words. They should provide factual information (e.g. conference venue, details of the conference organizers), present the various programme sessions and summarize the key research findings.
Book Reviews should be between 1,000 and 1,500 words. They should provide factual information (e.g. book publisher, number of pages and ISBN, price on the publisher's website) and critically discuss the contents of a book mainly in terms of its strengths and weaknesses.

Industry Perspectives should be up to 1,000 words and provide a practitioner's point of view on contemporary developments in the air transport industry. Contributors should explicitly specify whether their views are espoused by their organization or not.

Table of Contents

Forecasting has been a key factor in the planning and development of civil aviation. This paper surveys current techniques in air traffic forecasting. The advantages and disadvantages of the techniques, as well as the criteria for selecting of a particular technique are discussed. Then, the forecasting work of the International Civil Aviation Organization (ICAO) is comprehensively introduced, i.e. the traffic data, the methodological framework, and the major models. It involves ICAO's practices under this subject in the last two decades. ICAO's forecasting has long been a reliable reference for its 191 member states. In this paper, main results of ICAO's up-to-date forecasts of 2011-2030 global air traffic, both passengers and cargos, are conveyed.

While most of the research related to aircraft cabin safety has focused on fire, evacuation, and survival factors, it has been recognized that there are some other incidents that might affect flight safety and merit special attention. In Taiwan, a broad array of cabin incidents that have the potential to affect flight safety have been investigated and labeled as "abnormal cabin incidents," which include abnormal passenger behavior on board and medical problems. In the present study, the Brown-Gibson Model and Safety Risk Matrix were applied to investigate various ACIs. According to the results, sickness, injury, cell phone usage, the use of mobile electronics, unruly behavior, smoking, and carrying dangerous goods were categorized in the category of "acceptable with mitigation" proposed by the FAA. Excessive drinking, oral abuse, sexual harassment, physical assault, and other types of incidents were categorized in the "acceptable" group. These research results can be used to identify significant incidents related to flight safety and to allow appropriate resources allocation.

This study proposes a mechanism for measuring pilot-controller communication errors and develops a model to evaluate their communication performance. Empirical data based on 73 transcripts of communication from the Taipei Flight Information Region (FIR) are analyzed to validate the developed model and investigate communication issues. The results show that about 87% of all communication errors found in the transcripts had a relatively low level of influence on flight safety, while 13% had a severe influence. Additionally, the results of performance measurement indicate that the overall level of communication performance is relatively low. These findings are expected to be applicable to other countries whose native languages are not English. The performance model developed in this study can help management in the industry to evaluate radio communication performance of their aviation personnel.

Total Airport Management is a relatively new concept for a comprehensive optimization of airport processes. It is based on enhanced information sharing and communication among all stakeholders as well as on extended and improved forecasts of airport processes. The following paper describes a general concept for integrating landside passenger processes into Total Airport Management. It explains how landside stakeholders can be included in real collaborative decision making, in particular functionalities and Human Machine Interfaces of a prototypical TAM-compatible Passenger Management implementation called “PaxMan”. As a result of the improved linking of airside and landside processes, it is shown how airport stakeholders and passengers can benefit from this integration and from proactive airport operations.

Technology impact evaluations in air transport require the specification of environment conditions, such as the traffic structure. Since a multitude of worldwide traffic situations exists, this paper presents a systematic approach based on cluster analysis that can handle the worldwide diversity, while ensuring to determine most relevant traffic situations. This is crucial for the universality and global relevance of evaluation results. The approach is presented for the application example of runway capacity evaluation, as part of which features of daily movement distributions of airports and the traffic mix as well as peak situations are quantified. The resulting representative airport and peak categories comprise a limited set of typical traffic situations worldwide that can serve as standard input for capacity-related evaluation, ensuring comparability and clarity.

While some research has been done on passenger airlines strategy, the strategies of air cargo carriers have hardly been researched. This paper analyses and compares the strategies of air cargo carriers. Therefore, a typology of management strategies for both combination and full cargo airlines has been developed, in which the various strategy choices within the strategic framework of the respective air cargo carriers are further elaborated. The typology has been developed through a K-means cluster analysis on a data set of 47 air cargo carriers. The use of a cluster analysis to group the strategy models of a number of air cargo carriers is a novel feature of this research. The results of this research generate a typology of seven representative clusters of air cargo carriers’ strategy models, each with their own characterizing features. Striking differences and similarities are highlighted. Our findings suggest the clear existence of different strategy models and the differing degree of focus on air cargo strategy development and deployment among the air cargo carriers’ population.

This study researched whether pertaining to a global strategic alliance brought significant benefits to the ‘bottom line’ of allied airlines. The study compared the net return of airlines which had joined global alliances against a control group of airlines which had not joined any alliance before and after joining an alliance (or equivalent measure), as well as in their relative net performance both in the short-term and in a longer term. Results showed a sensible deterioration in net profitability for the alliance group and a perceptible improvement in net profitability for the non-alliance group. The latter also differed from the former in having a positive relative net performance in the short-term.

Editorial

Selected Papers from the 2012 ATRS World Conference

For this special issue of the *Journal of Air Transport Studies* we have selected seven papers out of 193 papers that were presented at the 16th Air Transport Research Society (ATRS) World Conference. The conference was held in Tainan, Taiwan, in June 2012 and attracted some 248 participants.

In order to give the reader an overview of several decisive issues in air transport, the first paper in this ATRS special issue gives insights to ICAO's forecasting process, the following two papers contribute to air transport safety, cabin incidents and ATC communication errors, while the next two papers lead the reader into the concept of total airport management and typologies for technology impact comparability in airports. In the subsequent paper we learn about the strategic development of cargo carriers and the last paper answers the question if alliances improve the bottom line of airlines. These papers, covered in more detail below, provide a valuable insight into current airport and airline issues.

As the industry is increasingly under pressure from various stakeholders that affect its ability to grow along the same trajectory as in the past, *forecasting* has taken on a new dimension where past methods of focusing on projecting past trends into the future are increasingly inadequate to understand the challenges that the industry may face in the coming decades. In the lead paper of this issue Yao, Yu, and Anwar discuss the benefits of current techniques in air traffic forecasting. They present the forecasting work of the International Civil Aviation Organization (ICAO) in detail and convey the main results of ICAO's 2011 to 2030 global air traffic forecast.

Safety is the one area of great importance for the industry necessitating research of any aspect of operations and human condition that can help prevent or manage dangerous incidents. Yen, Wang, Ye, Chen, K. K. Chang, Yu, Wu, Y. C. Chang, Ho and Lee research into cabin incidents that have the potential to affect flight safety such as abnormal passenger behavior and medical problems. The results suggest a two category allocation of incidents into "acceptable with mitigation" and "acceptable". The categorization of incidents suggested by this research can be used to identify incidents for proper evaluation and response.

Communication is the exchange of information between various posts of the air transport system. In view of the international character of the industry the meaning of exchanged words is codified to prevent as much as possible misunderstandings between operators in different countries. Yen, Wang, Tsai and Ho in their study propose a mechanism to evaluate communication performance of air traffic control. Their results show that the majority of communication errors had low influence on flight safety, while about 13% had a severe influence and the overall level of communication performance is relatively low. The authors assert that their performance model can help management to evaluate communication performance among aviation personnel.

Increasingly businesses and institutions understand the importance of the inter-linkages of various internal units with the external. How total activity systems can be fine-tuned to augment performance has become a major focus area in many subject areas. Helm, Classen, Rudolph, Werner and Urban present the concept of *Total Airport Management* for a comprehensive optimization of airport processes. The concept revolves around enhanced information sharing and communication among all stakeholders as well as on extended and improved forecasts of airport processes. The paper concludes that improved linking of airside and landside processes can benefit users and operators and lead to more proactive airport operations.

All airports are not created the same and understanding how different types of airports cluster around the world helps in analyzing and compare them. Öttl, Reeb, and Hornung present *airport categories for technology impact evaluation*. The paper uses cluster analysis to identify diverse airport categories worldwide. The results represent a set of typical traffic situations to use as input for capacity-related evaluation.

Surprisingly little academic research has focused on strategy among *air cargo companies*, a crucial business providing fast corridors for goods worldwide. Dewulf, Meersman and Van de Voorde research into and compare strategies of air cargo carriers using cluster analysis. Their findings suggest the existence of different strategies and degree of development and deployment among the air cargo carriers.

In the last, but not least paper of this special issue we learn about if *airline* *alliances* are really aiding the financial bottom line of the member airlines. Perezgonzalez and Lin in their study compare airlines that are members of a global alliance against airlines which are not. The results show deterioration in net profitability for the alliance group and a perceptible improvement in net profitability for the non-alliance group.

We take this opportunity to extend our thanks to the authors and referees for their contribution to this ATRS Special Issue of the *Journal of Air Transport Studies* and hope that the papers become a source for further inquiries into the respective topics.

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FORECASTING METHODS AND ICAO'S VISION OF 2011-2030 GLOBAL AIR TRAFFIC

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ABSTRACT

Forecasting has been a key factor in the planning and development of civil aviation. This paper surveys current techniques in air traffic forecasting. The advantages and disadvantages of the techniques, as well as the criteria for selecting of a particular technique are discussed. Then, the forecasting work of the International Civil Aviation Organization (ICAO) is comprehensively introduced, i.e. the traffic data, the methodological framework, and the major models. It involves ICAO's practices under this subject in the last two decades. ICAO's forecasting has long been a reliable reference for its 191 member states. In this paper, main results of ICAO's up-to-date forecasts of 2011-2030 global air traffic, both passengers and cargos, are conveyed.

Keywords: forecast, method, ICAO, air traffic, data, long-term

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Mr. Zubair Anwar has been working in ICAO on statistics and forecasting for over 30 years. He has participated in the establishment of the database of air traffic data of ICAO, as well as in all the forecasting activities of ICAO, either mid-term or long-term, ranging from regional level to global level.

1. INTRODUCTION

Reliable forecasts of civil aviation activity play a critical role in the planning process of states, airports, airlines, engine and airframe manufacturers, suppliers, air navigation service providers and other relevant organizations. In the civil aviation field, forecasts generally are used to:

- assist states in facilitating the orderly development of civil aviation and to assist all levels of government in the planning of airspace and airport infrastructure such as air traffic control, terminal facilities, access roads, runways, taxiways and aprons;
- assist airlines in the long-term planning of equipment and route structures; and
- assist aircraft manufacturers in planning future types of aircraft (in terms of size and range) and when to develop them.

The International Civil Aviation Organization (ICAO) is a specialized agency of the United Nations (ICAO, 2006). It stands for the safe and orderly development of civil aviation throughout the world, sets standards and regulations in all necessary fields, and serves as the global forum for the cooperation of its 191 Member States. Over 20 years, its Air Transport Bureau (ATB) has been conducting and publishing worldwide, regional, and route group air traffic forecasts.

Besides ICAO, there exist other deliverers of air traffic forecasting. Airbus (2011), as well as Boeing (2011), delivers its 20 years' market outlook timely, always aiming at the demand of aircrafts. The International Air Transport Association (IATA), which represents 230 airlines registered in 118 countries, provides five-year traffic forecasts for individual country-pairs (IATA, 2011), plus aggregate results at region and global level. Airports Council International (ACI) provides passenger forecasts over the next 20 years, based on over 300 member airports worldwide and on the latest traffic statistics (ACI, 2011). Some other companies, i.e. EMBRAER and Rolls-Royce, also publish their market forecasts with specific emphases.

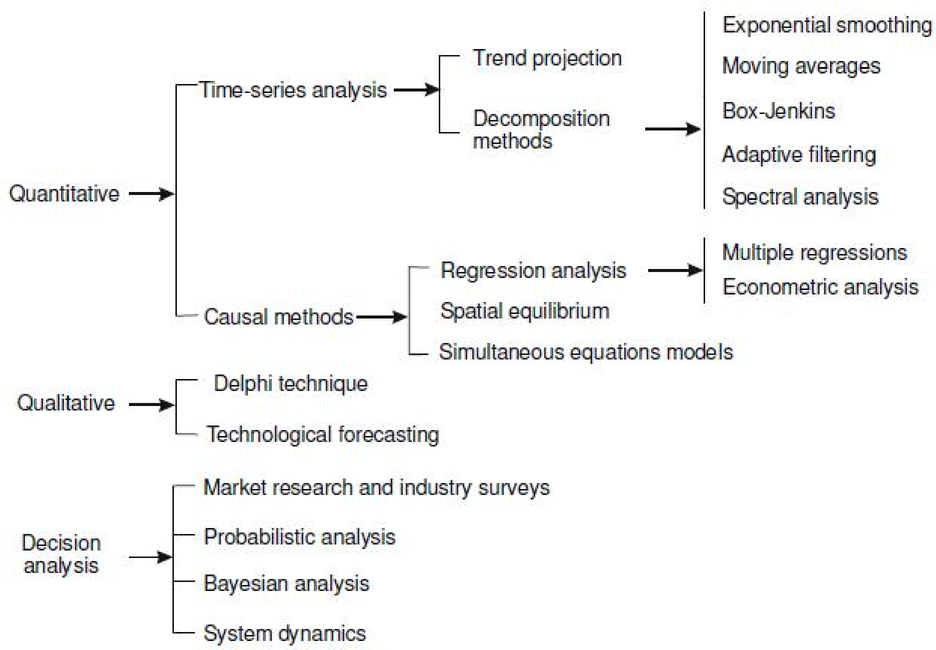
These forecasters differ in long-term or short-term, passenger or freight, world, regional or country level. Among all the forecasters, ICAO covers all the categories. For ICAO, forecasting serves as a global planning guideline for all member states, especially those countries that try to maintain sustainable growth in civil aviation. The reputation of the ICAO's forecasting is related to its duty as an inter-government non-profit organization.

In the following section, this paper surveys major forecasting techniques and the proper circumstances for their applications. Then the forecasting system of ICAO is introduced in Section III. The main results of ICAO's forecasts, i.e. ICAO's vision of 2011-2030 global air traffic, are presented in Section IV. The conclusions are addressed in Section V.

2. FORECASTING TECHNIQUES

Forecasting methods in air traffic can be divided into three categories: quantitative, qualitative/judgmental, and decision analysis. Forecasting techniques that start with historical data and develop a model based on a set of rules fall into quantitative methods.

Figure 1: Categories of Forecasting Techniques in Air Transport



2.1 Quantitative Methods

Quantitative forecasting methods can be classified into two subcategories: time-series analysis and causal methods.

2.1.1 Time-Series Analysis

A first step in quantitative forecasting is usually to study the historical air traffic data (time series) and the trend in traffic development. The time-series analysis methods are largely based on the assumption that historical patterns will continue, and they rely heavily on the availability of historical data (Chèze et al., 2010).

Trend projection applies mathematical techniques in determining the best fit line through the data. In the context of medium-term or long-term forecasting, the appropriateness of trend projection depends heavily on stability in past developments and the confidence of projecting trends into the particular future environment.

Decomposition methods involve the dissection of the problem into various components. These methods are particularly relevant when strong seasonality or cyclical patterns exist in the historical data. They are useful to identify three aspects of the underlying pattern of the data: the trend factor, the seasonal factor and any cyclical factor that may exist.

A general forecasting technique that attempts to deal with the fluctuations in a time series (trend, seasonality and cyclical factors) is smoothing (Aragon and Gnassou, 2008), i.e. moving average or exponential smoothing. The exponential smoothing emphasizes on the most recent data, to increase their influence on the forecast. So it is important to recognize the seasonality inherent in the data if monthly or quarterly forecasts are considered. A smoothing factor would determine how much weight is to be placed on, for example, various months of the year. The moving average differs from exponential smoothing in that each observation is weighted equally. Compared to exponential smoothing, the advantage of moving average is its simplicity, with a disadvantage that a longer data series is necessary.

Besides, there exist Box-Jenkins, Adaptive filtering, and Spectral analysis as members of the decomposition method. The method of Box-Jenkins handles complex time-series data (Andreoni and Postorino, 2006), where a variety of patterns exists such as a combination of a trend, a seasonal factor and a cyclical factor. The method allows for much flexibility, while also calling for much subjectivity. Adaptive filtering (Li et al., 2010) is another approach for determining the appropriate set of weights for each of the time periods. The process is repeated by adjusting the weights to reduce the error, where the final weights are to minimize the mean squared error. Spectral analysis can be used to study the cyclical variation over time. The data can be decomposed into a series of sine waves of different frequencies and magnitudes (Welch and Ahmed, 2003). This demands prior knowledge that such a form could be adapted in the forecasting process.

2.1.2 Causal Methods

Causal methods infer a cause-and-effect relationship, hence the name. They offer an alternative to time-series analysis by taking into account how economic, social and operational conditions affect the development of traffic. This process is actually a testing procedure, which is designed to evaluate whether the relationship of the dependent variable (as expressed in the causal model) to the independent (explanatory) variables is significantly related to the movements of these variables.

Regression analysis is by far the most popular method in civil aviation forecasting (Airport Authority Hong Kong, 2011; Taneja, 1978). The econometric model attempts to explain the demand for air travel as being caused by the changes in the explanatory variables. The use of multiple regression analysis with a price-income structure is generally referred to as econometric analysis or econometric modelling. Dependent variables, in general, are historical traffic data measured in terms of passengers or revenue passenger-kilometres (RPK) and tonnes of freight or freight-tonne kilometres (FTK). The explanatory (or independent) variables are those variables which would have an influence on the demand for air travel.

Spatial equilibrium models (Bröcker et al., 2003) establish a relationship for the movement of traffic between any two traffic centres or regions. In the basic form of this relationship, the traffic between each two points is directly proportional to some characteristic of the size of the region and inversely proportional to the distance between regions.

In a simultaneous equations model (Lu et al., 2003), the variables simultaneously satisfy all the equations. The model addresses the issue of supply-demand interactions. An advantage of the model is that it provides the values of several explanatory variables from within the model itself. However, estimation of the parameters of the equations involves more complex issues than those encountered in a single equation model.

2.2 Qualitative Methods

Qualitative forecasting methods are used when a number of historical observations are sparse or not available and where experience and judgment have to be used.

These methods can also be used in an assessment of how new technological or other developments would affect the forecast. They are largely intuitive and rely heavily on the judgment of experts and may be used to predict a significant change in historical patterns or, due to lack of sufficient historical data, for a quantitative analysis.

2.2.1 Delphi Technique

The technique has two steps. A selected group of experts are first presented with a questionnaire so that each expert indicates a most probable course of development in the activity being forecasted. The initial returns are then consolidated and the composite response returned to all contributors, giving them the opportunity to revise their original assessments in light of prevailing opinions among other experts. This technique is a practical means moving towards a consensus among experts.

2.2.2 Technological Forecasting

Technological forecasting method attempts to generate new information about future performance of systems. This information can be either explanatory or speculative in terms of what new developments will take place in certain areas and is used to obtain a better understanding of future expectations. Technological forecasting can be classified into two categories: explorative and normative.

2.3 Decision Analysis

Decision analysis should be considered as a combination of both quantitative and qualitative analysis methods. In decision analysis, the analyst's judgment is used in preparing forecasts for a particular area of expertise in combination with some statistical or mathematical techniques including subjective inputs of probabilities. Decision analysis is helpful in the assessment of uncertainty and in risk analysis.

2.3.1 Market Research and Industry Surveys

Traffic forecasting through market research surveys aims at analyzing the characteristics of the air transport market in order to examine empirically how the use of air transport varies between different sectors of the population and different industries. Such results, in combination with forecasts of socio-economic changes, may indicate the likely future development of air transport.

2.3.2 Probabilistic Analysis

There is uncertainty associated with the forecasted value. When the amount of uncertainty is large, it would be desirable to assign probabilities to the outcome of a variable or the forecast itself. Having a distribution of possible outcomes for a variable, and the range of the forecast can be assessed based on subjective probabilities.

2.3.3 Bayesian Analysis

Bayesian analysis is a procedure to improve a prior estimate using new data or using conditional regression, a method to refine prior estimates of the regression coefficients by using objective data. Coefficients of one of the explanatory variables can be assigned and the coefficients of the other variables can then be re-estimated. This process can be repeated until all relationships have been estimated.

2.3.4 System Dynamics

System dynamics techniques use large-scale computer models of integrated mathematical formulas and algorithms. Such methods can be used to simulate the behaviour of the system concerned in response to certain variables. The models may be used to evaluate alternative policy scenarios and their impact on aviation activity.

2.4 Forecasting Time Horizon

The length of forecasting time horizon may vary for the particular type of application concerned. It is actually a key criterion for matching a specific forecasting situation with the appropriate methodology. For the aviation industry, the following time horizons are generally used:

- Short-term: up to 1 year;
- Medium-term: 1 to 5 years;
- Long-term: more than 5 years.

Short-term forecasts generally involve some form of scheduling, which may include for example the seasons of the year, for planning purposes. The cyclical and seasonal factors are more important in these situations. Medium-term forecasts are generally prepared for planning, scheduling, budgeting and resource requirement purposes. The trend factor as well as the cyclical component plays a key role in the medium-term forecast because the year-to-year variations in traffic growth are an important element in the planning process. Long-term forecasts are used mostly in connection with strategic planning to determine the level and direction of capital expenditures and to decide on ways in which goals can be accomplished. The trend element generally dominates long-term situations. As the forecast horizon is long, it is also important that forecasts are calibrated and revised at periodic intervals. The methods generally found to be most appropriate in long-term situations are econometric analysis and life-cycle analysis.

3. ICAO'S FORECASTING SYSTEM

In the analysis of the real world, data collecting is the first step. ICAO has its own data reporting system by which each of the Member State contributes, monthly, quarterly, and yearly, to the air traffic data of ICAO. The Member States of ICAO also submit extensive data, such as On-Flight Origin and Destination and Traffic by Flight Stage provided historical passenger data by major route.

3.1 Data

Usually, the information that ICAO collects from its Contracting States is compiled into multiple data series. The data are updated in real time and change, often daily. These data series forms the base of the traffic database of ICAO. The database is now publicly accessible through the website of ICAOData (ICAO, 2013). It offers a user-friendly interface allowing for easy pick-up and analysis of the ICAO statistical data on the air transport industry.

3.1.1 Data Source

Data from traditional sources such as the Official Airline Guide, the airframe manufacturers and government data agencies provide additional depth. For the verification purpose of the reported data, ICAO keeps a continuously contact with other data collectors, such as IATA, OAG, and ACI. Besides the air traffic data, ICAO also purchased the econometric data package from Global Inside. These efforts make it possible for ICAO to conduct the analysis and the forecast of the air traffic.

3.1.2 Data Structure

As to the statistics of air traffic, the base data is the operation of a flight. It tells everything of the flight, such as original and destination airport, available and revenue seats, flight distance, flight hours, revue and total load, flight number, market type (international or domestic), etc. It could be a performed flight or a scheduled flight that has not yet been performed. Note that for a single flight, some data are calculated out upon some others. For example, the available seat kilometre (ASK) is the multiply of available seat number and flight distance. The revenue passenger-kilometre (RPK) is the multiple of revenue passenger and flight distance in kilometre. The revenue tonne-kilometre (RTK) is the multiple of revenue load in tonne and flight distance in kilometre. The load factor (LF) is the ratio of RPK versus ASK, representing the revenue level of a flight. Such type of data is named as city-pair data in the industry.

For a specified city-pair market, the data can be aggregated by time, by airline, by direction, etc. Different city-pair data can also be aggregated by origin/destination city, by country, or by region. For the forecasting purpose, ICAO defines 9 regions as the composition of the world, as shown in Figure 2. Then all the city-pair data are aggregated by its origin/destination region.

Figure 2: ICAO's Definition of 9 Forecasting Regions

Therefore, the traffic data fall into three categories: international traffic between regions, intra traffic between countries within a given region, and domestic traffic within a country of the region. Now that the world is divided into 9 geographical regions, forecasts will be developed for 53 route groups (36 inter-regions, 8 intra within region and 9 domestic within regions).

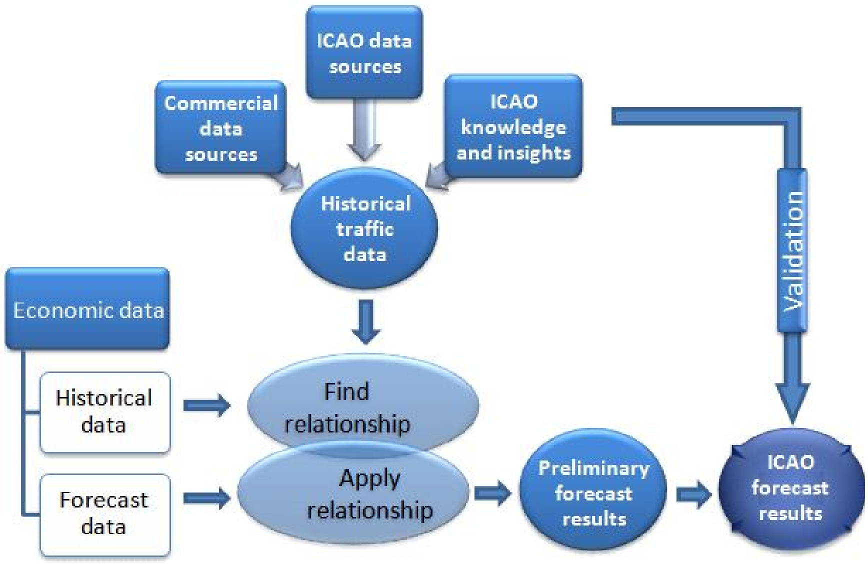
3.2 Methodology

In brief, the technique of linear regression has been used for the forecasts of RPK and FTK. Then the forecasts of aircraft movements are derived from these results, in addition to some assumptions on future passenger load factors, average aircraft seating capacity and average stage length by route group.

3.2.1 Framework

ICAO produces 20 year forecasts of air traffic to support aviation planning throughout the world. Figure 3 shows a simplified schematic diagram of the process.

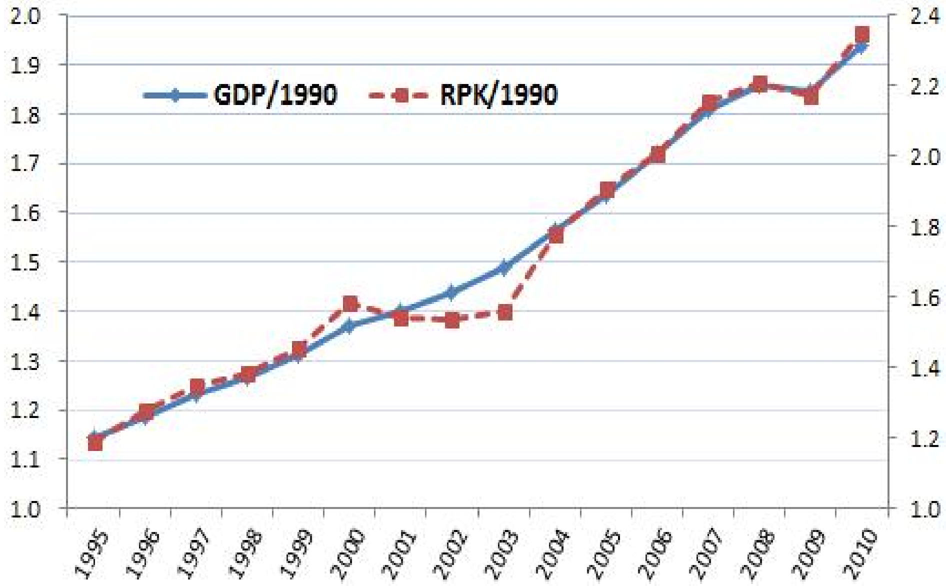
Figure 3: Forecasting Framework of ICAO



ICAO forecasters examined many non-aviation variables to find variables whose past history bears a strong relationship to air traffic. They apply mathematical methods to express historic air traffic in terms of these variables. ICAO has found that a region's Gross Domestic Product (GDP) tracks its air traffic consistently well. A relationship that expresses traffic in terms of GDP closely replicates the historical traffic. Fig. 4 shows the long-term relation between the growth of world GDP and the growth of world RPK.

GDP contains a very broad range of economic activity, and therefore has a minimal sensitivity to industry-specific fluctuations. It is a widely accepted index of economic prosperity. As GDP had a close relationship to air traffic in the past, it should maintain this relationship in the future. By "plugging in" the historical relationship into the future, the model should generate good forecasts of future air traffic.

Figure 4: Relation between World GDP and World RPK



3.2.2 Models for RPK and for FTK

ICAO forecasts revenue passenger-kilometres (RPK), freight tonne-kilometres (FTK), and aircraft movements for the major region-pairs and regions. The two former metrics reflect both the number of passengers and freight carried and the distances that they travel. It is presented hereby the detailed algebraic discussions of the estimation process. The basic model form assumed is:

$$y = a \cdot x_1^{b1} \cdot x_2^{b2} \qquad (1)$$

where, for the model of passenger traffic, y represents the RPK, x_1 is the GDP, and x_2 could be revenue per passenger-kilometre or a dummy variable; for the model of freight traffic, y represents the FTK, x_1 is world exports, and x_2 is freight revenue per freight tonne-kilometre or a dummy variable. The parameter a, b_1 and b_2 are constant coefficients whose values were obtained by statistical estimation, using econometric analysis. The b_1 and b_2 are equal to the elasticity of demand with respect to the corresponding x_1 and x_2.

The forecasts use the technique of linear regression. This involves examining one variable, in this case air traffic, against other variables from outside aviation. The goal is to find one or more variables which change over time, and whose changes are associated with changes in the air traffic variable. Annual data were used in the estimations, covering a period of 30 years for the model. A dummy variable could be introduced to take into account the special years where traffic and prices grew in the same direction.

3.2.3 Model for Aircraft Movement

Passenger traffic forecasts, expressed in terms of RPK, can be converted into forecasts of aircraft movements by using assumptions on future average load factor, average aircraft seating capacities and average distance stage length for each selected route group. It is described below the technical details concerning the methodology for forecasting aircraft movements.

The relationship between aircraft-kilometres, load factors and aircraft size (seats per aircraft) was developed for passenger aircraft as follows:

$$p = \frac{RPK}{\frac{RPK}{ASK} \cdot \frac{ASK}{p}} = \frac{RPK}{LF \times aircraft\ size} \qquad (2)$$

where p stands for aircraft kilometres.

Forecasts of aircraft movements incorporate assumptions about future passenger load factors, average aircraft seating capacity and average stage length by route group. Load factors on all route groups are expected to increase over time but would not exceed 85%. At this level, air carriers are assumed to switch to larger aircraft or to add frequencies. The trend of average aircraft seating capacity depends on the route groups. For mature and highly competitive markets, such as Domestic North America, where frequency is a major determinant of market share, aircraft seating capacity is projected to decrease, whereas for developing long haul markets, such as Europe-Middle East and all routes between Middle East and Asia/Pacific, aircraft seating capacity is projected to increase. Average stage length is expected to increase on the majority of route groups.

The average growth rate of aircraft kilometres in the history was then used to calculate the forecast number of aircraft kilometres for all scheduled services, including all freight as well as combined passenger and freight services. Then the relation between aircraft departures, aircraft kilometres and aircraft stage length for passenger and all freight aircraft combined is derived as follows:

$$q = \frac{p}{p / aircraft\ movements} = \frac{p}{stage\ length} \qquad (3)$$

where q represents the aircraft movements. The forecast for aircraft movements in the future was generated by substituting into this expression the forecast for aircraft kilometres and the assumption for the growth of average stage length in the future.

4. ICAO'S VISION OF 2011-2030 GLOBAL AIR TRAFFIC

By 2011, some regions and region-pairs had attained maturity, with large per-capita aviation use, price-sensitive customers and a stable industry structure. Others were relatively undeveloped, hence performing sustained growth. These different conditions have led to apparent different growth rates for commercial aviation around the world.

4.1 Global Passenger Traffic

Recent historical and future traffic are hence derived for all world air routes. By 2030, an average annual growth rate (AAGR) of 4.5% for world total passenger traffic will result in 2.3 times of RPKs of the 2011 level. Growth during the 2020-2030 will fall slightly as markets mature. Domestic traffic will grow slightly slower than international travel volumes. Improved surface transportation, particularly high speed rail, will absorb part of the demand for air transport.

4.1.1 Passenger Traffic at a World Level

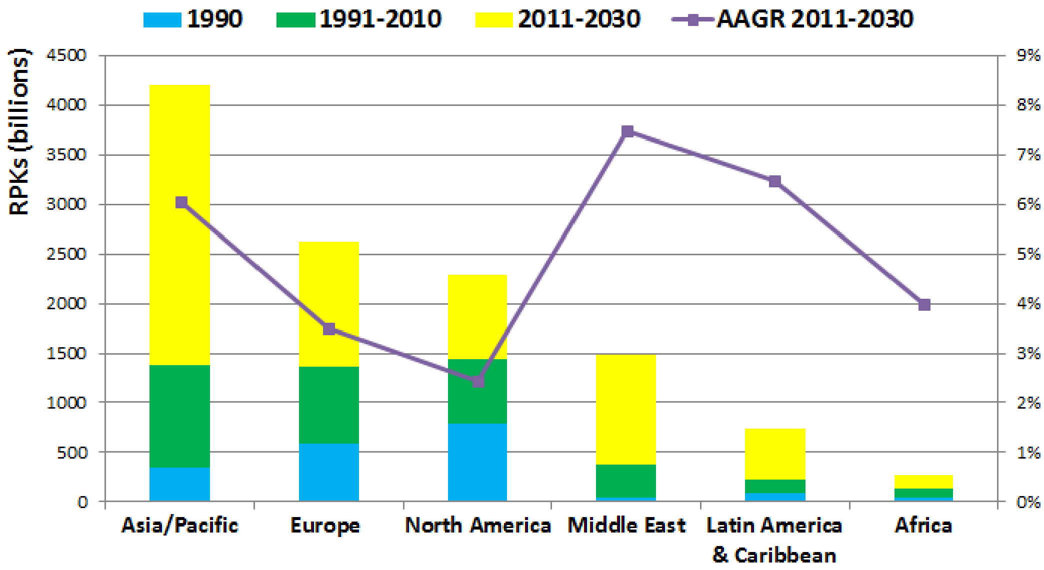
Economic processes are hard to forecast, and some regions will deviate from the most likely assumptions. ICAO therefore prepared two further sets of forecasts, the high (optimistic) and a low (pessimistic) to measure the consequences of our uncertainty about the future. Over the period 2011-2030, the high forecast for global passenger calls for an average annual growth rate of 5.1% per year. A rate of 3.6% annually would result from the assumptions in the low scenario.

Table 1: Summary of Passenger RPK Forecasts
by Region of Airline Registration

Region	Growth Rate (%)		Share of World Total (%)		
	1990-2010	2011-2030	1990	2010	2030
Africa	5.5	4.0	2.2	2.6	2.3
Asia/Pacific	6.8	6.1	18.2	27.4	36.2
Europe	4.1	3.5	31.2	27.9	22.6
Middle East	10.5	7.5	2.5	7.4	12.8
North America	3.0	2.4	41.4	30.1	19.7
Latin America & Caribbean	4.5	6.5	4.6	4.5	6.4
WORLD	4.6	4.6	100	100	100

The forecasts of by region of airline registration may differ from the forecasts by route group. Since most countries reserve domestic traffic exclusively for their own registered airlines, the domestic route group will be served by regionally domiciled carriers. A route group's trans-border traffic will be served primarily by regionally based carriers, although airlines from other regions may hold international traffic rights within that region.

Figure 5: Passenger RPK Forecasts by Region of Airline Registration



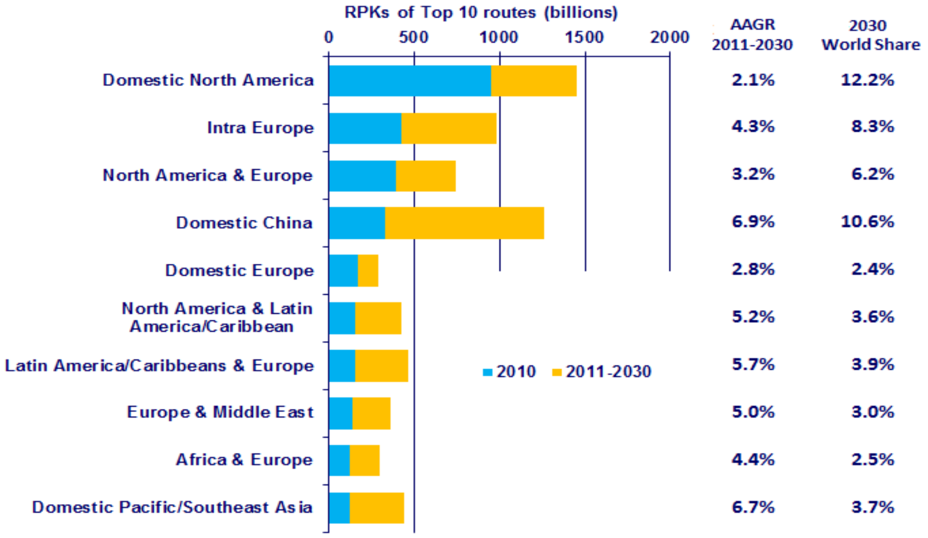
The airlines of two separate regions will share the inter-regional traffic. Bilateral agreements, negotiated on the balance of benefits principle, would lead in theory to equal traffic shares. In practice, the airlines of one region might substantially out-carry those of the other. Carriers based outside either of the two regions may also capture a share of the traffic. For example, Delta Air Lines and United Airlines both carry local traffic between Tokyo and Singapore.

Unlike the route group forecasts summarized previously, the "Asia-Pacific" route in this part includes China, North Asia, Pacific/South East Asia and Southwest Asia. The sustainable growth of the Asia/Pacific region is significant. Its strong economic growth will have propelled it, from the sixth largest market in 1990 to the largest in 2030 in terms of passengers. North America will have the lowest growth, and its world rank will fall from the first to the third. The North American carriers' declining share results from low population growth, stodgy growth in the GDP, and the already extensive use of commercial aviation in 2011. North American markets have the longest post-liberalization experience, and the stimulus was already reflected in the historical volumes.

4.1.2 Passenger Traffic Forecasts of Major Routes

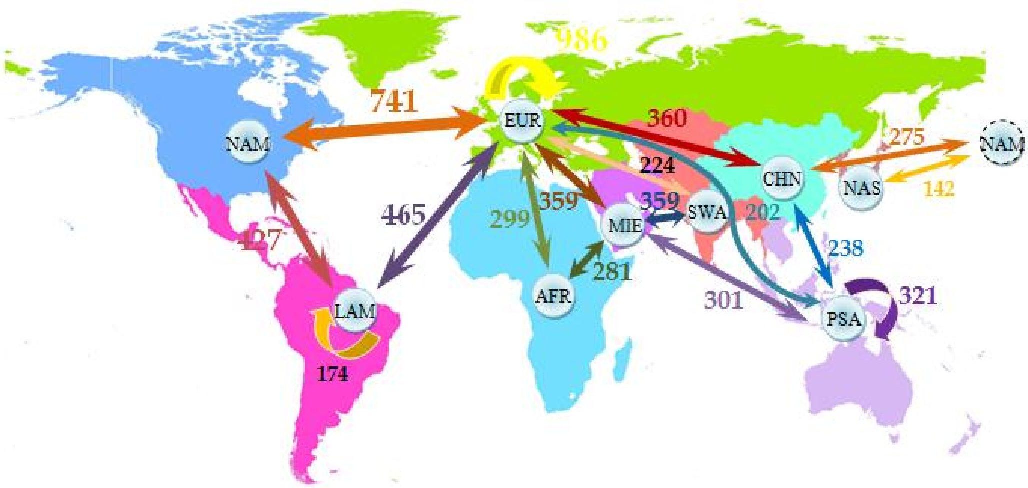
For the next two decades, the AAGR of route group RPKs is range from 1.0% for Domestic Northeast Asia to 9.1% for Middle East - Africa.

Figure 6: Top Ten Passenger Traffic Routes in 2011 and Growth 2011-30



The Intra Europe route will remain the largest international route by 2030. Europe stays the major motor of international passenger traffic in 2030, see Figure 7 below.

Figure 7: Major Routes of International Passenger Traffic in 2030



Still, the air network of Middle East will be reinforced as the region rises up as the hub between Europe, Asia, and Africa.

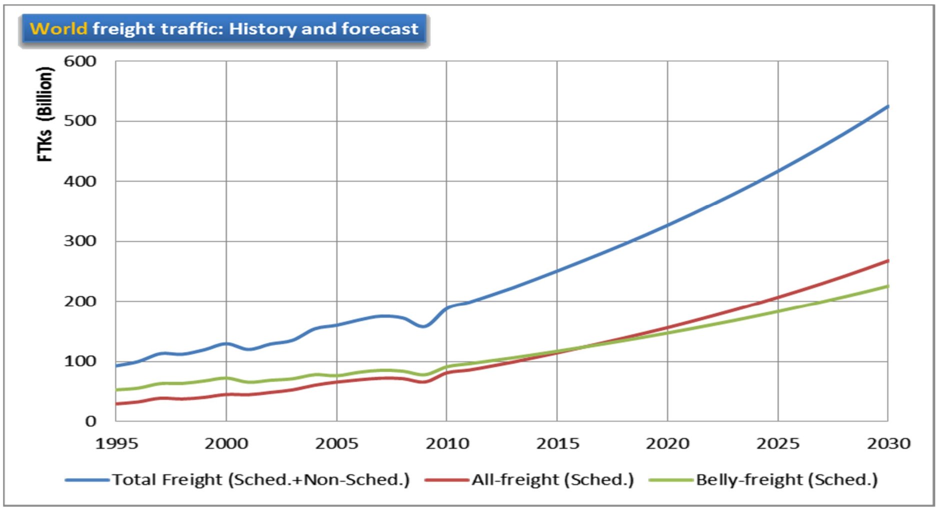
4.2 Global Cargo Traffic

By 2030, the 5.3% annual growth in total freight traffic (Scheduled and non scheduled flights) will result in an increase of 2.7 times the 2010 level. Domestic traffic will grow at the same pace with international travel volumes.

Table 2: Summary of FTKs Forecasts by Region of Airline Registration

Region	FTKs (million)			AAGR (%)		World Share (%)		
	1990	2010	2030	1990-2010	2011-2030	2000	2010	2030
Africa	1126	2284	4638	3.6	3.5	1.8	1.3	0.9
International	1035	2198	4536	3.8	3.6	2.0	1.5	1.1
Domestic	91	86	102	-0.3	0.8	0.5	0.3	0.1
Asia/Pacific	16340	62812	212157	7.0	6.2	33.9	36.3	43.0
International	14832	55537	186443	6.8	6.2	36.1	38.0	44.7
Domestic	1508	7275	25714	8.2	6.5	20.3	27.4	33.7
Europe	20008	44576	89646	4.1	3.6	29.5	25.8	18.2
International	17413	43832	87900	4.7	3.6	33.5	30.0	21.1
Domestic	2595	744	1746	-6.1	4.4	5.0	2.8	2.3
Middle East	2440	16191	72118	9.9	7.4	3.9	9.4	14.6
International	2351	16095	72000	10.1	7.4	4.4	11.0	17.3
Domestic	89	96	118	0.4	1.1	0.6	0.4	0.2
North America	16176	40938	92140	4.8	4.3	27.1	23.7	18.7
International	8533	24671	50866	5.5	3.9	20.2	16.9	12.2
Domestic	7643	16267	41274	3.8	4.8	69.3	61.3	54.1
Latin America & Caribbean	2736	6022	22870	4.0	7.5	3.8	3.5	4.6
International	2183	3943	15500	3.0	8.0	3.7	2.7	3.7
Domestic	553	2079	7370	6.8	6.5	4.3	7.8	9.7
WORLD	58826	172823	493569	5.5	5.4	*100*	*100*	*100*
International	46347	146276	417245	5.9	5.4	*100*	*100*	*100*
Domestic	12479	26547	76324	3.8	5.4	*100*	*100*	*100*

Figure 8: Forecasting of World Air Freight



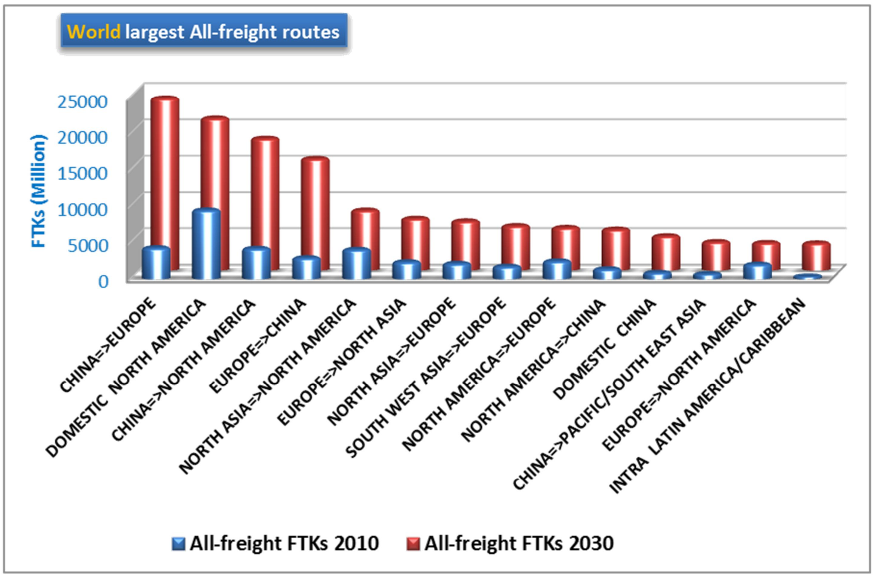
All-dedicated freight traffic will grow faster than Belly-freight traffic. In 2010, the freight carried by Freighter represents 47% of the total freight traffic. In 2017, that all-dedicated freight traffic will cross the symbolic market share of 50% to reach in 2030 a 54% market share.

4.2.1 All-Freight Global Results

According to ICAO's forecasts, all-freight traffic will grow at 6.2% per year for the next 2 decades.

All-freight traffic from China to Europe will grow much faster than the Domestic North America all-freight market. Further, Domestic North America all-freight traffic will become the second largest route in 2030 as measured by Freight tonnes-kilometres carried, the China to Europe route traffic coming to the first rank.

Figure 9: 2030 Rankings for All-Freight Traffic



International routes will represent 89% of the world all-freight traffic. International all-freight traffic will be dominated by China to Europe, followed by China to North America, which will account together for 18% of the traffic. Domestic all-freight traffic will be dominated by North America, followed by China, which will account together for 90% of the world domestic traffic.

4.2.2 Belly-Freight Global Results

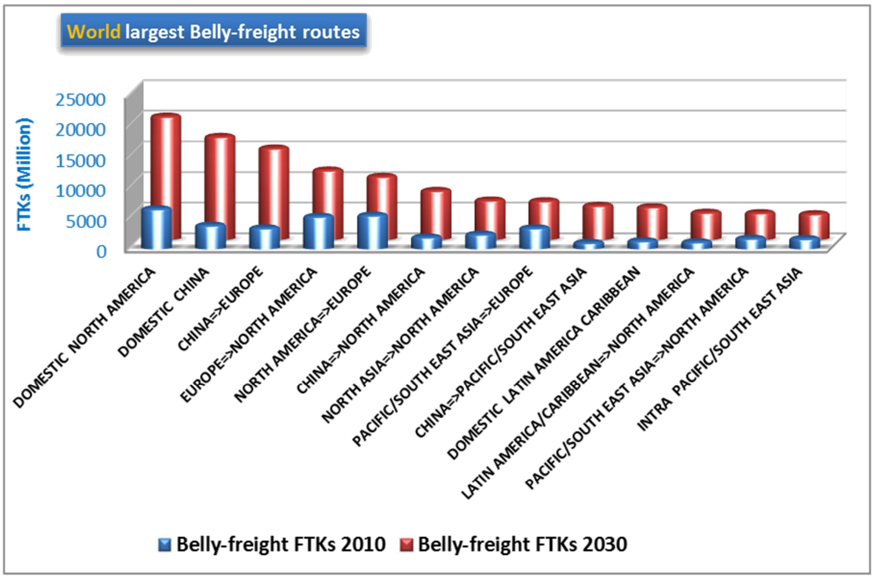
International routes will represent 79% of the total belly-freight traffic in 2030, a 5% decrease from the 2010 market share. Therefore, domestic traffic is going to increase faster than international traffic. International Belly-freight traffic will be dominated by China to Europe, followed by Europe to North America, then North

America to Europe, and only in fourth position China to North America. According to ICAO's forecasts, belly-freight traffic will grow at 4.6% per year for the next 2 decades. Domestic North America belly-freight traffic will remain the largest market as measured by freight tonnes-kilometres (FTK) carried in 2030. Domestic belly-freight traffic will be dominated by North America, followed by China, which will account together for 78% of the traffic in 2030.

4.3 Global Aircraft Movements

Along with the RPKs forecasting, the aircraft movement is very important for airport planning. The forecasts help airports determine the number of runways they need and the total land that they will require. It is also an important factor in the need for ATC facilities and for the development of new international routes.

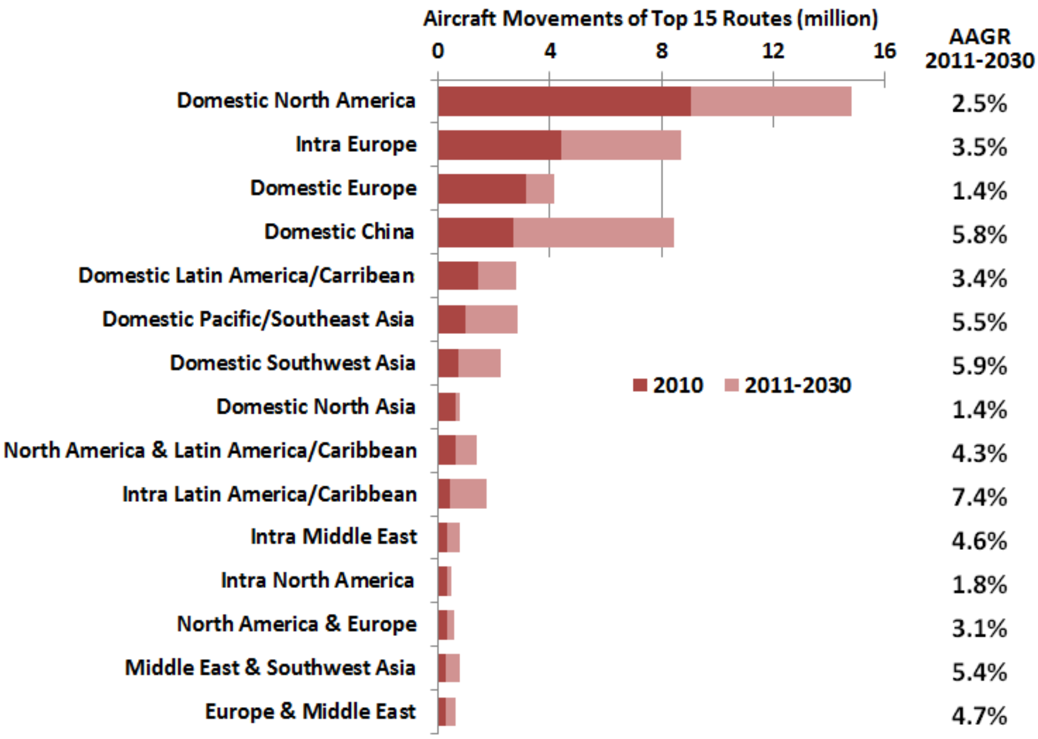
Figure 10: 2030 Rankings for Belly-Freight Traffic



Factors such as the technology available, how airlines manage the available capacity, the types of aircraft used and the structure of airline networks are of crucial importance in defining the number of flight operations. Pricing concerns are also important, since premium business passengers tend to require high frequencies. Very high load factors tend to correspond to low average fares.

The forecasts of aircraft movements closely parallel the forecasts of RPKs. North America, North Asia and Europe are all large and mature regions. They will grow relatively slowly to 2030. China, Southwest Asia, and the Pacific/Southeast Asia regions will experience rapid growth. Other regions, including the Middle East, Africa and Latin America will also see robust growth.

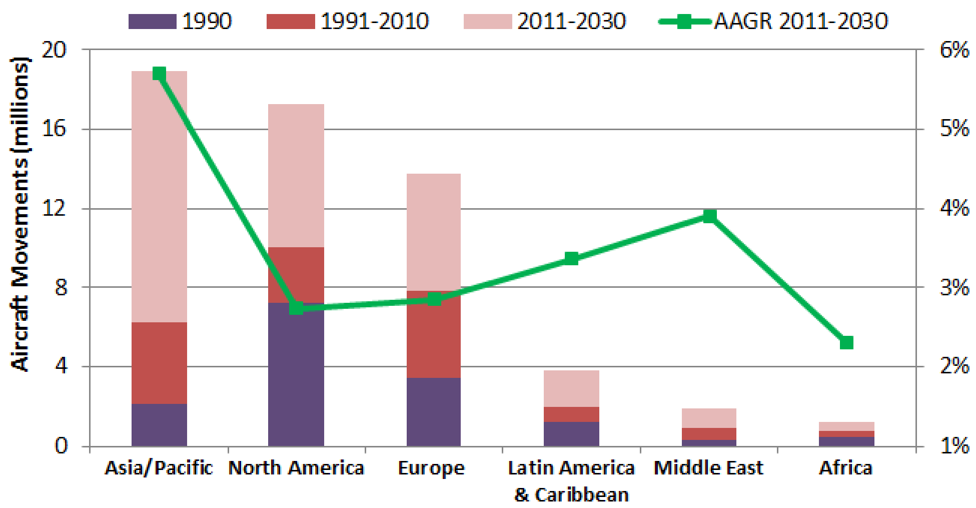
Figure 11: Forecasts of top 15 Routes of Aircraft Movements



4.3.1 Forecasts of Passenger Aircraft Movements by Regions

The growth of air travel has been particularly beneficial to developing countries. Airlines of Southeast Asia, Latin America and Africa are capturing a growing share of total traffic.

Figure 12: Forecasts of Aircraft Movements by Region of Airline Registration



Global aircraft movements (excluding all freight movements) are forecast to grow at the average annual rate of 3.6% over the period 2011-2030, compared to 3.2% for 1990-2010. The main reasons for this difference are the projected improvements in load factors and overall increases in average aircraft seating capacity and in range. Asia/Pacific airlines, including those of China and Southwest Asia, will experience particularly rapid growth. Only they will exceed the world average, and only they will increase their share of the total world aircraft movements.

4.4 Global Pilot Demand

During the last decades, strong growth of commercial air transport has led to many new commercial air transport operators and the highest number of aircraft orders ever registered. Over the next 20 years, the demand for qualified aviation personnel, such as pilots, aircraft maintainers, and air traffic controllers will need to be correlated to aircraft delivery plans. Using its breadth of civil aviation expertise, ICAO estimated current and future requirements for civil aviation personnel and training capacity in each region (ICAO, 2011). The table below summarizes the forecast on pilot demand and training capacity in 2030.

Table 3: Summary of Pilot Forecasts by Region of Airline Registration

Region	Pilot Demand	Training Capacity	Assessment
Europe	15532	7955	SHORTAGE
Asia/Pacific	13983	4935	SHORTAGE
North America	10449	27655	SURPLUS
Latin America	6250	1945	SHORTAGE
Africa	3814	1010	SHORTAGE
Middle East	2458	860	SHORTAGE
World Total	52506	44360	SHORTAGE

5. CONCLUSIONS

This paper has surveyed current techniques in air traffic forecasting. Besides, the forecasting work of ICAO is comprehensively introduced. The main results of ICAO's forecasts of 2011-2030 global air traffic have been presented, serving as a reliable reference for its 191 member states.

In the aviation industry, the forecasts rely heavily on the historical data. Traffic by Flight Stage (TFS) information and On-flight Origin/Destination statistics for air carriers are different from the traffic data for airports. It is rare that one could get all data from a single data provider. The situation often gets complicated as the provider has only part of the historical data. For example, some of the member states have been reporting to ICAO the traffic data from 1950, while many other states have only provided the data in the recent 30 or even 20 years.

It is interesting to compare the results from different forecasters. It is not easy, however, to achieve the comparison, in view of their differences in data sources, in ways of aggregating data, and in forecasting techniques. Different forecasting techniques may apply to best fit the application situation. For example, aircraft manufacturers such as Boeing and Airbus, conduct their forecasts of RPK/FTK, as well as of the global/regional fleet that depends on the airplanes in service, airplanes removed from service, and the new airplane deliveries. Nevertheless, it is remarkable to note, for a comparative study, that the definition of global regions by ICAO (see Fig.2) is different from both that of Boeing and from that of Airbus.

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REFERENCES

- Airbus (2011), *Global Market Forecast: 2011-2030*, Blagnac: Airbus.
- Airport Authority Hong Kong (2011) Air Traffic Demand Forecast. In: *HKIA Master Plan 2030 - Technical Report*, Hong Kong: Airport Authority Hong Kong.
- Airports Council International (2011), *Global Traffic Forecast*, Available from: http://www.aci-forecast.aero
- Andreoni, A., Postorino, M.N., (2006) A multivariate ARIMA model to forecast air transport demand. *Proc. Association of European Transport 2006*. Strasbourg, September 12-15.
- Aragon, Y., Gnassou, S., (2008) Estimation of air traffic loss at Toulouse Blagnac Airport after September 11, 2001 attacks. CS-BIGS, 2(1), 1-8.
- Boeing (2011), *Current Market Outlook 2011*, Seattle: Boeing.
- Bröcker, J., Capello, R., Lundquist, L., (2003) Spatial-Equilibrium Model of Trade and Passenger Flows. In: *Territorial Impacts of EU Transport and TEN Policies*, Brussels: European Commission.
- Chèze, B., Gastineau, P., Chevallier, J., (2010) Forecasting Air Traffic and Corresponding Jet-fuel Demand until 2025 (Working Paper), Rueil-Malmaison: IFP energies nouvelles.
- International Air Transport Association (2011), *Airline Industry Forecast*,

Montreal: IATA.

- International Civil Aviation Organization (2006). *Convention on International Civil Aviation* (Doc7300/9), Montreal: ICAO.
- ICAOdata (www.icaodata.com) (2013) A website that is being developed, operated, and marketed by International Civil Aviation Organization (ICAO).
- International Civil Aviation Organization (2011) *Global and Regional 20-year Forecasts: Pilots, Maintenance Personnel, and Air Traffic Controllers*, Montreal: ICAO.
- Li, W., Barros, A., Romani, I., (2010) *Computational Models, Software Engineering, and Advanced Technologies in Air Transportation: Next Generation Applications*, 1st edition. Hershey: Engineering Science Reference.
- Lu, I.L., Peixoto, J., Taam, W., (2003) A simultaneous equation model for air traffic in the New York area. *7th Air Transport Research Society World Conference*. Toulouse, July 10-12.
- Taneja, N.K., (1978) *Airline Traffic Forecasting: a Regression-analysis Approach*, Lexington: Lexington Books.
- Welch, J.D., Ahmed, S., (2003) Spectral analysis of airport performance. *AIAA's 3rd Annual Aviation Technology, Integration, & Operations (ATIO) Forum*. Denver, November 17-21.

MODELING THE RISK OF ABNORMAL CABIN INCIDENTS IN TAIWANESE AIRLINES: AN APPLICATION OF THE BROWN-GIBSON MODEL AND FAA SAFETY RISK MATRIX

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ABSTRACT

While most of the research related to aircraft cabin safety has focused on fire, evacuation, and survival factors, it has been recognized that there are some other incidents that might affect flight safety and merit special attention. In Taiwan, a broad array of cabin incidents that have the potential to affect flight safety have been investigated and labeled as “abnormal cabin incidents,” which include abnormal passenger behavior on board and medical problems. In the present study, the Brown-Gibson Model and Safety Risk Matrix were applied to investigate various ACIs. According to the results, sickness, injury, cell phone usage, the use of mobile electronics, unruly behavior, smoking, and carrying dangerous goods were categorized in the category of “acceptable with mitigation” proposed by the FAA. Excessive drinking, oral abuse, sexual harassment, physical assault, and other types of incidents were categorized in the “acceptable” group. These research results can be used to identify significant incidents related to flight safety and to allow appropriate resources allocation.

Keywords: cabin abnormal incident, cabin safety, aviation security, Brown-Gibson Model, FAA Safety Risk Matrix.

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1. INTRODUCTION

Issues related to cabin safety have been investigated for decades. While most of the research has been focused on fire, evacuation, and survival factors, it has been recognized that some other cabin incidents that take place in flight due to passenger misconduct could affect flight safety and merit special attention (e.g., Hsu and Liu, 2012). In the US, the most frequently reported incidents through the NASA's Aviation Safety Reporting System were "unruly passengers" and "drunken passengers" (ASRS, 2000). It has been recognized that such incidents have a significant bearing on the cabin crew's obligation to ensure the observance of safety regulations and the comfort of other passengers on board, as well as to prepare for unexpected accidents that might call for emergency evacuation (Kao et al., 2009; ASRS, 2003; Edwards, 1990). Additionally, these incidents may affect flight operations that are directly related to flight safety. For example, according to ASRS (2000) 43% of the incidents distract flight crews from their duty, and in 22% of cases, a flight crew member had to leave the cockpit to assist cabin crew in dealing with an unruly passenger. The situation becomes even worse if the distraction takes place during the crucial approach and landing phases.

There is no unique definition of these cabin incidents in aviation practice or academia. In Taiwan, a broad array of incidents have been investigated and labeled as abnormal cabin incidents (ACIs) by the Flight Safety Foundation –Taiwan (FSF-Taiwan, 2007) and their implications on flight safety addressed. According to FSF-Taiwan, ACIs involve abnormal passenger behavior on board such as the usage of cell phones/electronics, excessive drinking, smoking, oral abuse, physical assault, sexual harassment, unruly behavior, carrying dangerous goods, and others. Additionally, passenger sickness and injury are also included in the investigation. In total there are twelve categories of ACIs under investigation. FSF-Taiwan has analyzed ACI data reported from all six Taiwanese airlines since 2001. Statistics from FSF-Taiwan (2007) showed that there were 471 ACIs reported in 2001. This number increased to a record high of 1748 in 2006, a 3.7 fold increase. The present study recognizes the potential impact of ACIs on flight safety and is aimed at applying the concept of risk assessment to investigate the risk of various ACIs. Specifically, a Brown-Gibson model is also used to combine subjective judgment and information obtained from objective data.

The concept of risk assessment and Brown-Gibson modeling is discussed in the next section, followed by a presentation of the empirical study. Research findings and their implications on risk mitigation are discussed in section four. Finally, some conclusions are offered.

2. METHODOLOGY

2.1 Definition of Risk, Frequency and Consequence

In the safety research literature, a risk can be considered as a combination of the probability or frequency of a defined occurrence or hazardous event and the magnitude of consequences or severity of the occurrence or event (Netjasov & Janic, 2008; Bahr, 1997). In the present study, since ACIs might affect the safety-related duties of flight and cabin crew, they can be considered an occurrence or hazardous event which needs to be investigated. In terms of the probability or frequency of each occurrence, data collected by FSF-Taiwan from six Taiwanese airlines were used as an objective measure of relative frequency. On the other hand, it is recognized that data from carriers' reports might not reflect the full range of actual events (Kao et al., 2009). Additionally, Boksberger et al. (2007) addressed the issue of perceived risk in air travel and cited Peter and Ryan's (1976) definition of perceived risk as the judgment on the likelihood of negative outcomes and the degree of negativity. Therefore, opinions about how frequently each occurrence might take place were obtained from fifteen experts. These opinions were used as a subjective measurement of relative frequency. Additionally, the FAA (2010) defines likelihood as the estimated probability or frequency, in quantitative or qualitative terms, of an occurrence related to the hazard. Hence the term "likelihood" is used hereafter in this paper when assessing the risk of each ACI. The objective and subjective measurements of likelihood are then combined to represent the likelihood of each ACI and used in the risk assessment. The Brown-Gibson model is employed to combine the objective and subjective data as described in the following section.

2.2 Brown-Gibson Model

The idea of the Brown-Gibson model (BGM) was first proposed to select plant locations (Brown & Gibson, 1972) and has been used for strategic decision analysis (Feridun et al., 2005; Punniyamoorthy & Ragavan, 2003). In the BGM, both subjective and objective factors related to a specific decision problem are converted into consistent and dimensionless indices. The weighted measurement is calculated by a weighting sum of both converted indices as presented in equation (1). The BGM is applied to estimate the likelihood of each ACI of interest.

$$WL_i = (\alpha)\,(OM_i) + (1-\alpha)\,(SM_i) \qquad (1)$$

In equation (1), WL_i is the weighted measurement of the likelihood of ACI i; OM_i and SM_i are the objective and subjective measurements of the likelihood of ACI i, respectively; α is the objective weightage with an interval between 0 and 1. Since both the values of OM_i and SM_i are also between 0 and 1, the calculated WL_i is less than one and greater than zero, with the highest likelihood of occurrence being 1 and the lowest one 0. By definition, when α is set to be one WL_i is equal to OM_i and is equivalent to the objective measurement. On the other hand, when α is set to be zero WL_i is equivalent to the subjective measurement (SM_i).

2.3 Risk Assessment

The FAA Safety Risk Matrix (SRM) can be used as a vehicle to assess the risk of each ACI. The risk analysis and risk assessment of FAA uses a conventional breakdown of the risk of an identified hazard based on two components: likelihood of occurrence and severity of consequence. Five categories were suggested for each component by the FAA. The likelihood ranges from 5 (the highest level) to 1 (the lowest level). The severity is categorized from A (the most severe) to E (the least severe). According to the FAA, each aviation operator's specific definitions for severity and likelihood may be qualitative or, preferably, quantitative. Thus a common SRM can be constructed in Table 1 (FAA, 2010) to evaluate the acceptability of risk.

As shown in Table 1, the FAA defines three areas of acceptability: unacceptable, acceptable, and acceptable with mitigation (AWM). For a risk categorized as "unacceptable," further work is required to eliminate the associated hazard or to control factors that lead to higher risk likelihood or severity. Where the risk assessment falls into the AWM category, the risk may be accepted under the defined conditions of mitigation. When the assessed risk falls into the "acceptable" category, it may be accepted without further action. However, the FAA suggests aviation operators always reduce risk to as low as practicable regardless of whether or not the assessment shows that it can be accepted as is.

Table 1: The Safety Risk Matrix Proposed by the FAA

severity likelihood	E	D	C	B	A
5			5C	5B	5A
4	4E			4B	4A
3	3E	3D			3A
2	2E	2D	2C		
1	1E	1D	1C	1B	

Note: unacceptable (3A-5A, 4B, 5B, 5C); acceptable (1E-4E, 1D-3D, 1C, 2C, 1B); acceptable with mitigation (AWM; other cells)

3. EMPIRICAL STUDY

3.1 Weighted Measurements of Likelihood

The purpose of the present study is to assess the risk of each ACI and thus assist the related authorities and airlines to identify the higher risk ACIs. As mentioned in section 2, the risk of an ACI is the combination of its probability or frequency and its magnitude of consequences or severity. To consider both objective and subjective information, the probability of each ACI is represented by the weighted likelihood as formulated in equation (1), based on the BGM. FSF-Taiwan (2007) has collected the numbers of each ACI reported by six Taiwanese airlines in 2006. The objective measurement of the likelihood of each of the twelve ACIs was obtained by calculating the relative frequency of each ACI, and is listed in the fourth column of Table 2.

The subjective information was obtained by conducting a survey to elicit opinions from fifteen experts in the aviation arena, including government officers, airline management, researchers, and senior cabin crew members. Every expert was asked to express his/her judgment on the likelihood of each ACI. The likelihood was divided into three categories low, medium, and high indicated by numbers 1, 2, and 3, respectively, for calculation of the subjective measurements of likelihood. The calculation is shown below.

$$SM_i = \Sigma_n SL_{ni} / \Sigma_i \Sigma_n (SL_{ni}). \qquad (2)$$

In equation (2), SL_{ni} is the subjective measurement of the likelihood of ACI i, elicited from the expert n. SL_{ni} could be a number such as 1, 2, or 3. The notation of $\Sigma_n(SL_{ni})$ represents the summation of the subjective measurements of SL_{ni} across all fifteen experts. By definition, both OM_i and SM_i can be considered to be dimensionless indices and can be applied to equation (1) to calculate the weighted measurement of the likelihood of ACI i. The calculated results of the SM_i, i=1,2, ..., 12, and associated WL_i are also listed in Table 2, with α varying from 1.0, 0.0, to 0.5. The numbers in Table 2 indicate the standardized likelihood of each ACI from the point of view of objective measurement (α=1.0), subjective measurement (α=0.0), and equally weighted measurements (α=0.5).

As mentioned in section 2.3, the FAA defines five categories of likelihood for each hazard in the SRM, without explicitly explaining how to obtain these categories quantitatively. Since the purpose of this study is to identify the relative significance of twelve ACIs as defined in Table 2, the relative frequency (likelihood) of each ACI is used to define the likelihood category. As shown in Table3, if the standardized likelihood of ACI i is greater than the mean value (MEAN) plus one unit of standard deviation (SD) ACI i is categorized as level 5, the highest likelihood of occurrence. On the other hand, if the standardized likelihood of ACI i is less than the MEAN minus 0.5 units of SD ACI i is categorized as level 1 with the lowest likelihood. The likelihood category of each ACI is also included in the parenthesis right after the associated standardized likelihood in Table 2. As listed in the objective measurement column (OMi) of Table 2, sickness (SI) has the highest likelihood of occurrence and is the only item included in the highest likelihood category 5, which is followed by injury (IN), the only one in category 4, and using cell phones (CP), the only one in category 3. The likelihood category 2 contains four ACIs, namely unruly behavior (UB), others (OT), smoking (SM), and excessive drinking

(ED). The category with the least likelihood includes all five other ACIs, that is using mobile electronics (ME), oral abuse (OA), sexual harassment (SH), physical assault (PA), and carrying dangerous goods (DG).

Table 2: Measurements of Likelihood and Severity of Each ACI for Taiwanese Airlines

Abnormal cabin incident		Objective measurement of likelihood (OM_i)		Subjective measurement of likelihood (SM_i)	Weighted measurement of likelihood (WL_i)	Subjective measurement of severity
		Number	Standardized likelihood (α=1.0)	Standardized likelihood (α=0.0)	Standardized likelihood (α=0.5)	1: not at all; 2: a little; 3: neutral; 4: severe; 5: very severe
sickness	SI	745	0.426 (5)	0.112 (5)	0.269 (5)	3.13 (E)
injury	IN	278	0.159 (4)	0.088 (3)	0.124 (4)	3.80 (C)
cell phone usage	CP	179	0.102 (3)	0.096 (4)	0.099 (3)	4.07 (B)
unruly behavior	UB	127	0.073 (2)	0.063 (1)	0.068 (2)	4.47 (A)
Others	OT	125	0.071 (2)	0.084 (3)	0.078 (2)	3.13 (E)
Smoking	SM	124	0.071 (2)	0.100 (4)	0.086 (3)	3.80 (C)
excessive drinking	ED	103	0.059 (2)	0.092 (3)	0.076 (2)	3.67 (D)
using mobile electronics	ME	31	0.018 (1)	0.096 (4)	0.057 (2)	3.73 (D)
oral abuse	OA	19	0.011 (1)	0.084 (3)	0.048 (1)	3.27 (E)
sexual harassment	SH	10	0.006 (1)	0.068 (1)	0.037 (1)	3.13 (E)
physical assault	PA	5	0.003 (1)	0.060 (1)	0.032 (1)	4.20 (B)
carrying dangerous goods	DG	2	0.001 (1)	0.060 (1)	0.031 (1)	4.93 (A)
Total (mean)		1748	1.000 (0.083)	1.000 (0.083)	1.000 (0.083)	(3.78)

Table 3: Algorithm for Categorizing Twelve ACIs

Levels of likelihood (severity)	Category interval
5 (A)	> MEAN + 1.0 SD
4 (B)	(MEAN + 0.5 SD, MEAN + 1.0 SD)
3 (C)	(MEAN, MEAN + 0.5 SD)
2 (D)	(MEAN - 0.5 SD, MEAN)
1 (E)	< MEAN - 0.5 SD

The subjective information elicited from fifteen experts (the SMi column) has the most similarity with the OMi column, with SI, IN, and CP being included in the highest three categories and SH, PA, and DG being included in the lowest category. There are two major differences between the objective and the subjective measurements. First, the difference of likelihood between the ACIs with the highest likelihood and the second highest likelihood from objective measurements (SI vs IN) is much greater than the one obtained from subjective measurements (SI vs CP). Secondly, there are substantial differences in the categories of SM, ME, and OA from different measurements, with aviation experts perceiving higher likelihood than what is actually reported by airlines. Not surprisingly, the information revealed by the equally weighted measurement (WLi, $\alpha = 0.5$) falls between that revealed by the objective and subjective measurements.

3.2 Measurements of Severity

Severity is the other important component when measuring the risk of a hazard. Severity can be defined as the degree of loss or harm resulting from a hazard. The severity of the consequences of some ACIs is easy to identify. For example, it is apparent that the consequences of a bomb explosion on the airplane would be extremely severe. Fire caused by smoking in the cabin may result in a disaster if the fire is not extinguished immediately. The risk of passenger sickness results from the likelihood of diversion and the possibility of disease transmission onboard. On the other hand, the consequences of some ACIs are not easy to identify or they may depend on the situation when the ACIs occur. For example, the severity of the consequence of excessive drinking depends on whether or not flight crew experience distraction from their flying duties due to this incident or the behavior of the drunken passenger such as trying to open the exit door in the air.

Studies related to the objective measurements of the consequences of each ACI are limited. The present study employs subjective measurements. In addition to eliciting the subjective measurement of the likelihood of each ACI as mentioned in the previous section, each expert was asked to express his/her judgment about the influence of each ACI on flight safety should the incident take place. There were five levels of influence for the respondent to choose from, not at all, a little, neutral, severe, to very severe, with equivalent scores of 1, 2, 3, 4, and 5, respectively, when calculating the severity of each ACI. The average level of severity of each ACI across all fifteen experts is listed in the last column of Table 2. As indicated in Table 2, DG (carrying dangerous goods) has the greatest average score of 4.93, with almost all experts rating as the highest level of severity (5). Experts rated UB (unruly behavior) as having the second highest level of severity, which is followed by PA (physical assault) and CP (using cell phone). All of these four ACIs have rating scores greater than 4.0, which is equivalent to the severe level. On the other hand, SI (sickness), SH (sexual harassment), OA (oral abuse), and OT (others) are rated with relatively low levels of severity, with scores less than 3.5, equivalent to the neutral level.

As discussed in section 2.3, the FAA divides the severity of a hazard into five categories, from the most severe A to the least severe E. The same algorithm (Table 3) of categorizing likelihood is employed to divide twelve ACIs into five categories using data in the last column of Table 2, with the severity category of each ACI included in parenthesis right after the associated average score. As shown in Table 2, category A consists of DG and UB, category B contains PA and CP, category C includes SM and IN, and category D comprises ED (excessive drinking) and ME (using mobile electronics). Finally, SI, SH, OA, and OT are contained in category E.

3.3 The ACI Safety Risk Matrix

The safety risk matrix (SRM) proposed by the FAA (2010; 2006) is used to obtain the risk of each ACI. In the FAA SRM, both the likelihood and severity of occurrences are divided into five categories as mentioned in section 2.3. The categorization of empirical data in terms of likelihood and severity is conducted in sections 3.1 and 3.2, and the results are listed in Table 2. The resulting SRMs based on the categorization of twelve ACIs are presented in Tables 4, 5, and 6, with the values of alpha setting as 1.0, 0.0, and 0.5, respectively.

As indicated in Table 4, the SRM with the alpha setting of 1.0 (using objective measurements of likelihood only), there is no ACI within the unacceptable area. Five types of ACIs are contained in the AWM area: SI, IN, CP, UB, and UB. Taking the information in Table 4 a step further reveals that SI falls into this area because of its high level of likelihood, while DG and UB are in the same area because of their high level of severity. Additionally, IN has a relatively high level of likelihood and a medium level of severity, whereas CP has a relatively high level of severity and a medium level of likelihood. The other seven ACIs fall into the acceptable area because of their low level of likelihood, with PA and SM having relatively high levels of severity.

Most of the information shown in Table 5, obtained with an alpha setting of 0.0 and using only subjective measurement of likelihood, is similar to the information revealed in Table 4, with only a little variation. First, CP moves from the AWM area to the unacceptable area. Secondly, SM and ME move from the acceptable area to the AWM area. Both of the above movements are due to the increase in the likelihood of the subjective measurement, compared with the objective measurement.

Table 4: Results of the FAA Safety Risk Matrix (□= 1.0)

severity likelihood	E	D	C	B	A
5	SI				
4			IN		
3				CP	
2	OT	ED	SM		UB
1	OA; SH	ME		PA	DG

Table 5: Results of the FAA Safety Risk Matrix (□= 0.0)

severity likelihood	E	D	C	B	A
5	SI				
4		ME	SM	CP	
3	OT; OA	ED	IN		
2					
1	SH			PA	DG; UB

The information in Table 6 (alpha setting of 0.5) is shared with that in Table 4 with only one exception, which is the change of SM from the acceptable area in Table 4 to the AWM area in Table 6 due to the increase in likelihood.

Table 6: Results of the FAA Safety Risk Matrix (□= 0.5)

severity likelihood	E	D	C	B	A
5	SI				
4			IN		
3			SM	CP	
2	OT	ED; ME			UB
1	OA; SH			PA	DG

The commonality of information in Tables 4, 5, and 6 indicates that the SRM of ACIs is fairly stable in various cases where the weights of the objective and subjective likelihood measurements vary. According to the commonality revealed in those three tables, the twelve types of ACIs can be grouped into two areas. The AWM area includes SI, ME, SM, IN, CP, UB, and DG while OT, OA, SH, ED, and PA, on the other hand, are in the acceptable area.

4. PRACTICAL IMPLICATIONS OF THE RESULTANT ACI SAFETY RISK MATRIX

The objective of this research is to identify significant abnormal cabin incidents related to flight safety and then suggest appropriate measures to reduce the risk arising from these incidents. The results of FAA SRM shown in Tables 4, 5, and 6 provide fundamental information regarding the risk of each ACI and its associated likelihood of occurrence and severity of effect. This information is essential to further develop suitable measures to reduce the risk for each ACI. To achieve this goal the twelve types of ACIs can be regrouped into seven categories as shown in Table 7, based on the information provided in Tables 4, 5, and 6. For comparison, categories 1 (*Acceptable I*) and 2 (*Acceptable II*) are equivalent to the acceptable area in the FAA SRM, and are considered as ACIs with lower risk. Categories 3 to 7 (*AWM I* to *AWM V*) are equivalent to the AWM area with medium risk.

Table 7: Regrouped Categories of ACIs with Measures to Reduce Risk

Category	ACI	Reasons to be in this category		Practical measures
		Level of likelihood	Level of severity	
Acceptable I	OA; SH; OT	relatively low	lowest	Accept without further action.
Acceptable II	PA	lowest	relatively high	Reduce the severity of consequences should the incident occur.
AWM I	DG; UB	lowest	highest	Keep the likelihood as low as practical and reduce the severity of consequences should the incident occur.
AWM II	SI	highest	lowest	Reduce the likelihood and prevent possible transmission of disease.
AWM III	CP	medium	relatively high	Reduce both the likelihood of occurrence and the severity of the consequences.
AWM IV	SM; IN	medium to relatively high	medium	Reduce the levels of both likelihood and severity with equal priority.
AWM V	ME; ED	medium to relatively low	relatively low	Reduce the levels of both likelihood and severity with the former being a higher priority.

ACIs included in *Acceptable I* are OA, SH, and OT because of their lowest level of severity and relatively low level of likelihood (levels *1-3*). According to the suggestions made by the FAA, the risk of these incidents can be accepted without the need for further action. To further reduce the risk, however, we suggest that airlines take actions to reduce their likelihood. Flight attendants are usually the targets of oral assault/sexual harassment. As mentioned by some experts in our interview panel, the organization's support and assistance to flight attendants when OA or SH takes place can reduce the likelihood of these incidents. The most useful support and assistance is to provide flight attendants with the necessary resources to take legal action against the offenders.

Physical assault (PA) is categorized in *Acceptable II*, with the lowest likelihood but relatively high severity of consequence. It is essential for the airline to reduce the level of severity of this type of incident in order to mitigate its risk. In most cases, physical assaults take place between passengers. In these types of situation, an immediate aircrew/cabin crew intervention can alleviate the severity of the incident. Additionally, other passengers may be useful resources for assistance.

The category of *AWM I* is similar to *Acceptable II* with the lowest level of likelihood but the highest level of severity. DG and UB fit within this category. Carrying dangerous goods is considered the ACI with the highest level of severity because they could cause explosion or fire onboard or function as a weapon to attack flight/cabin crew. Unruly behavior includes incidents such as trying to open the exit door while in the air, destroying smoke detectors in the lavatory, or physically assaulting flight/cabin crew. Although DG and UB have the lowest level of likelihood, aviation operators (including airline and other security-related authorities) need to do their best to keep the likelihood as low as possible. Well-designed security checks with respect to passengers and check-in/carry-on luggage is of paramount importance to lower the likelihood of DG or to prevent pans to use carry-on weapons to assault flight crews/attendants. When either DG or UB incidents take place, the intervention of a well-trained crewmember or an air marshal on some specific flights is critical to prevent the worst consequences.

Sickness (SI) is contained in category *AWM II*, with the highest level of likelihood and the lowest level of severity. The priority should be to reduce the likelihood of sickness during the flight. Ill passengers with certain specific diseases should be denied boarding to prevent transmission in the cabin. Screening for passengers' temperatures before boarding or requiring ill passengers to obtain medical approval prior to boarding is a good measure to reduce the likelihood of SI incidents. Additionally, placing a health information card in the seat pockets to remind passengers to avoid "cabin-related risk factors" will decrease the possibility of deep vein thromboses. Making antiseptic liquid soap or alcohol-based hand gels available to passengers has the potential to reduce the transmission of some infectious diseases. Although the severity level of sickness is rated as the lowest one from the prospective of flight safety, recruiting flight attendants with nursing/medical training or hiring third-party services to supply in-flight diagnostic and medical advice via direct radio links is a useful measure to reduce the severity should a sudden serious medical condition occur.

Categories *AWM III* and *AWM IV* are similar, with both likelihood and severity being above the medium level. The former is comprised of CP (using cell phones; medium likelihood and relatively high severity). The latter contains SM (smoking) and IN (injury), both with the medium to relatively high level of likelihood and the medium level of severity. In both categories, likelihood and severity are of the same importance to reduce the risk of ACIs in these two categories. For example, using cell phones on board might affect the electronic devices on the airplane and thus might influence flight safety. The safety briefing before takeoff will reduce the likelihood of using cell phone or smoking in flight. Increasing the monetary penalty or including the behavior of CP and SM on board under criminal law will also reduce the likelihood of occurrences. Additionally, smoke detectors in the lavatory and well-trained flight attendants can reduce the severity should a passenger smoke on the airplane which could cause a fire.

ME (using mobile electronics) and ED (excessive drinking) are included in category *AWM V*, with a medium to relatively low level of likelihood and a relatively low level of severity. Similar to the previous two categories, both likelihood and severity need to be reduced in *AWM V*, with likelihood being a higher priority. Measures to reduce the likelihood of ME are the same as CP mentioned in the previous section. Although the consequence of ED seems to not to be severe, it might cause other incidents such as UB, PA, SH, and OA and needs to be carefully dealt with. Discontinuing the supply of alcoholic drinks to a passenger with a sign of intoxication is a good way to avoid ED in flight and prevent other associated abnormal behavior. Additionally, if passengers can be monitored for erratic behavior prior to boarding, especially for signs of intoxication, and denied boarding if their behavior is likely to continue during flight, the likelihood of drunken behavior on board can be reduced.

5. CONCLUSION

The issue of abnormal cabin incidents has been recognized for decades. Systematic study of this topic based on empirical data, however, has been limited. The present research employs the FAA safety risk matrix to investigate the risk of twelve types of ACIs. According to the FAA, a risk is a combination of the likelihood of a defined hazard and the severity of the hazard. To establish the SRM, two sets of data need to be obtained, namely the likelihood of occurrence of each ACI and the associated severity should it take place. In terms of the likelihood of each ACI, both objective and subjective measurements are used, with the former reported from six Taiwanese airlines and the latter elicited from fifteen aviation experts. When the objective measurement of the severity of each ACI is not available, only subjective opinions from those fifteen experts are included in the analysis. Based on the analysis of three types of data combinations with respect to the likelihood of each ACI, namely objective measurements, subjective measurements, and equally weighted measurements, the resulting three SRMs are consistent to some extent. That is, the empirical data reported by airlines and subjective opinions elicited from experts share a substantial level of similarity. Hence, we have confidence that the research results are robust enough to interpret the risk of each type of ACIs. The associated measures proposed to reduce risk are thus useful to aviation operators.

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REFERENCES

- ASRS (2000) ‘Passenger misconduct effects on flight crews’, *CALLBACK from NASA’s Aviation Safety Reporting System*, No. 250, April 2000.

- ASRS (2003) 'Safety in the cabin', *CALLBACK from NASA's Aviation Safety Reporting System*, No. 282, March 2003.
- Bahr, N. (1997) *System Safety Engineering and Risk Assessment: A Practical Approach*. Taylor and Francis, London.
- Boksberger, P.E., Bieger, T., Laesser, C. (2007) 'Multidimensional analysis of perceived risk in commercial air travel', *Journal of Air Transport Management* 13, 90-96.
- Brown, P.A., Gibson, D.F. (1972) 'A quantified model for facility site selection application to multiplant location problem', *AIIE transaction* 4(1), 1-10.
- Edwards, M. (1990) 'Human factors in the aircraft cabin', *Cabin Crew Safety* 25(6), 1-4, Flight Safety Foundation.
- FAA (2006) *Advisory Circular.* AC 120-92.
- FAA (2010) *Advisory Circular*. AC 120-92A.
- Feridun, M., Korhan, O., Ozakca, A. (2005) 'Multi-attribute decision making: an application of the Brown-Gibson model of weighted evaluation', *Journal of Applied Sciences* 5(5) 850-852.
- FSF-Taiwan (2007) 'Analysis of Taiwan carrier's cabin abnormal events in 2006', *Flight Safety Quarterly* 49, April 2007.
- Hsu, Y.-L., Liu, T.-C. (2012) 'Structuring risk factors related to airline cabin safety', *Journal of Air Transport Management* 20, 45-56.
- Kao, L.-H., Stewart, M., Lee, K.-H. (2012) 'Using structural equation modeling to predict cabin safety outcomes among Taiwanese airlines', *Transportation Research Part E* 45, 357-365.
- Netjasov, F., Janic, M. (2008) 'A review of research on risk and safety modelling in civil aviation', *Journal of Air Transport Management* 14, 213-220.
- Peter, J.P., Ryan, M. (1976) 'An investigation of perceived risk at the brand level', *Journal of Marketing Research* 13, 184–188.
- Punniyamoorthy, M., Ragavan, P.V. (2003) 'A strategic decision model for the justification of technology selection', *The International Journal of Advanced Manufacturing Technology* 21, 72-78.

MODELLING THE ORAL COMMUNICATION PERFORMANCE OF AIR TRAFFIC CONTROL

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ABSTRACT

This study proposes a mechanism for measuring pilot-controller communication errors and develops a model to evaluate their communication performance. Empirical data based on 73 transcripts of communication from the Taipei Flight Information Region (FIR) are analyzed to validate the developed model and investigate communication issues. The results show that about 87% of all communication errors found in the transcripts had a relatively low level of influence on flight safety, while 13% had a severe influence. Additionally, the results of performance measurement indicate that the overall level of communication performance is relatively low. These findings are expected to be applicable to other countries whose native languages are not English. The performance model developed in this study can help management in the industry to evaluate radio communication performance of their aviation personnel.

Keywords: oral interaction, flight safety, air traffic control, communication errors, communication performance.

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1. INTRODUCTION

Efficient and appropriate communication between flight crews and Air Traffic Controllers (ATCs) is a major determinant of flight safety in the commercial aviation industry. Unfortunately, communication barriers do exist between pilots and ATCs, which can cause problems, even fatal aviation accidents. The Tenerife collision of two B-747 airplanes in 1977, the fuel starvation crash at the JFK airport in 1990, and the collision over India in 1996 are only a few examples that highlight defects with English communication among flight crews and ATCs. On the basis of a review of 340 accidents from January 1986 to September 1988 carried out by Morrison and Wright (1989), it was found that 42% of accidents can be attributed to communication errors. According to Rakas and Yang (2007), seventy percent of operational errors and pilot deviations were caused by communication problems. Recognizing the importance of language proficiency in pilot-controller communication, the International Civil Aviation Organization (ICAO) has set mandatory aviation English proficiency standards that are required of international pilots and ATCs. Additionally, Tsai (2009) reported that respondents believed familiarity with radiotelephony phraseology to be more important than English proficiency to ensure the accuracy and clarity of pilot-controller communication. The majority of subjects also indicate that training rather than testing is necessary to ensure the quality of pilot-controller communication, though in reality, the focus of aviation authorities and operators is more on testing than training.

In radiotelephony communication, there are more opportunities for communication with a pilot or controller who is a non-native speaker of English. While native speakers of English use different accents, non-native speakers use even more varieties of English. This raises questions concerning English limitations. Thus, radiotelephony phraseology plays a critical role in pilot-controller communication

(Tsai, 2009). To ensure safe, efficient, and coordinated movement of aircraft at international airports, pilots and ATCs have to improve both their English competence and radiotelephony phraseology.

Noble (2002) reviewed related research and concluded that assessing the language proficiency of nonnative English-speaking pilots in flight presents many challenges. He indicated that such proficiency cannot be measured directly and it can only be measured by observers in flight and is limited to reading the dials and instruments within the cockpit. Most research in the literature related to oral communication between pilots and ATCs focused on how communication context increased the workload of ATCs (eg. Galster et al., 2001; Metzger and Parasuraman, 2001; Wiersma and Mastenbroek, 1998). Recently, Skaltsas et al. (2013) made an effort to define communication errors and investigated factors that affect communication. The authors defined two types of communication errors: mishearing and not responding. They investigated a database of controller-pilot voice messages from high and super-high altitude en-route sectors of US airspace and concluded that the most important factors were length and context of the message, and radio frequency congestion.

On the basis of our literature review, quantitative models that measure the performance of oral communication with respect to communication errors are not available. Thus, the goal of the present research is to identify and categorize communication errors between pilots and ATCs from the prospective of radiotelephony phraseology, set up a mechanism to measure these communication errors, and finally develop a model to evaluate communication performance based on the number and severity of communication errors.

The concept for measuring communication errors and evaluating communication performance is discussed in the next section. The third section presents an empirical study with research findings and their implications on aviation safety. Finally, some discussions and conclusions are offered.

2. METHODOLOGY

2.1. Definition of Communication Errors

According to Shannon and Weaver (1949), communication includes a sender, a receiver, and some sources of disturbances. In the communication between pilots and air traffic controllers, either a pilot or a controller could be a sender or a receiver. The present study defines a communication error as a situation in which the information transferred between senders and receivers is influenced by some disturbances and results in a difference of understanding between both parties. It has been recognized that the disturbances result from four types of factors. Human factors are generally recognized as the main factor leading to communication errors. Other factors such as language barriers, environmental factors and communication technology also affect the efficiency and accuracy of communication between pilots and ATCs. Grayson and Billings (1981) and Monan (1998) made efforts to categorize the communication errors between pilots and controllers, including the contradiction between what one intends to say and the actual wording. This study, however, does not investigate the contradiction between a person's intention and his actual words and assumes a consistency between the speaker's intention and the spoken sentences. Only errors attributed to communication are investigated. Based on an in-depth literature review, twelve types of communication errors between pilots and controllers are defined, as listed in Table 1.

Table 1: The Definition of Error Types

	Error Type	Definition
T_1	Information not on time	The timing of information transfer is not right, making it not useful.
T_2	A controller forgets a delivered clearance	The controller forgets that he/she has already delivered a clearance in a communication.
T_3	Misunderstanding	Though the sender delivers a piece of information that is suitable, precise, and understandable, the receiver reads back correctly but misunderstands it.
T_4	Syntax error	The pattern, grammar, and vocabulary is imprecise and there exists a risk of misunderstanding.
T_5	Call-sign error	Omitting a call sign, or using an incorrect/unauthorized call sign.
T_6	Incorrect read back/listening	Some keywords are omitted or incorrect in reading back.
T_7	Incomplete clearance/information	The clearance or information delivered by a controller is incomplete, e.g., wind direction, QNH, flight information, direction, and altitude.
T_8	Incorrect reply	Pilots or controllers misunderstand the call sign and reply.
T_9	An incorrect call	A controller delivers a clearance to the wrong receiver, or the pilot calls the wrong control unit (probably using the incorrect frequency).
T_{10}	No reply	A party that has been called does not reply.
T_{11}	Incorrect phraseology	The sender uses incorrect phraseology.
T_{12}	Inefficient correction (repeated errors after being corrected)	The receiver finds an error in communication and tries to correct the sender, but the sender makes the same mistake in the next reply.

2.2. Mechanism for Measuring Communication Errors

A communication cycle i under investigation may make e_{ij} number of errors T_j, where j=1, 2,..., J. Here J is the number of error types defined by the researchers. J is equal to twelve in this study. Therefore the number of errors made during a communication cycle (i) between parties A and B ($E_{A\text{-}B,\ i}$) can be calculated as in equation (1).

$$E_{A\text{-}B,\ i} = e_{i1} + e_{i2} + \ldots\ldots + e_{i12} \qquad (1)$$

A communication cycle may include a few sentences between a sender and a receiver and both reach an agreement very quickly. The following fictional example of communication between AIR001 and Taipei Tower (TT) exemplifies how a pilot-controller communication cycle is formed. There is no error in this communication; therefore, $E_{AIR001\text{-}TT}$ is equal to zero.

AIR001: *Taipei tower, ready to taxi, AIR001.*

Tower: *AIR001, taxi to Runway 05 via Taxiway SS, SP, Taipei tower.*

AIR001: *Taxi to Runway 05 via Taxiway SS, SP, AIR001.*

In other cases, a communication may take a few minutes and barely reach an agreement. While errors may occur at any moment in an exchange between pilots and controllers, the severity of their potential consequences varies depending on their flight phase. A complete flight can be divided into nine phases: taxi, takeoff, initial climb, climb, cruise, descent, initial approach, final approach, and landing. Table 2 lists the possible communication contents in these flight phases. In practice, a communication cycle usually includes only one or a few communication contents. As shown above, the communication between AIR001 and Taipei Tower is comprised of contents H_1 and H_4.

Table 2: Possible Contents in a Communication Cycle

	Content
H_1	Pilots establish two-way communication with controllers
H_2	Request for clearance delivery
H_3	Request for startup/pushback
H_4	Taxiing instructions
H_5	Takeoff clearance
H_6	Change of flight headings, altitude, and speed
H_7	Holding instructions
H_8	Radar vector for approach
H_9	Landing clearance
H_{10}	Frequency change
H_{11}	Position confirmation
H_{12}	Traffic information
H_{13}	Declare an emergency

In order to take the severity of potential consequences into account, the relative influence of communication cycle i on flight safety can be quantified by S_i as calculated in equation (2). In equation (2), W_h is the relative influence of content h on flight safety and H is the number of types of possible contents in a communication. Here, H is 13; I_h is an index, with its value being equal to one if communication cycle i contains content h, zero otherwise.

$$S_i = I_1 W_1 + I_2 W_2 + \ldots + I_h W_h + \ldots + I_H W_H \qquad (2)$$

Thus, the number of errors made during a communication cycle (i) between parties A and B can be represented by $E_{A\text{-}B,\,i}$ as calculated in equation (1), or by a weighted vale of $WE_{A\text{-}B,\,i}$ to address the relative influence of communication cycle i. The value is defined as the product of S_i and $E_{A\text{-}B,\,i}$. If there are more than one communication cycles between a pilot (party A) and a controller (party B), the weighted communication error between A and B ($WE_{A\text{-}B}$) can be calculated using equation (3), where Y is the number of communication cycles between parties A and B.

$$WE_{A\text{-}B} = S_1 E_{A\text{-}B,\,1} + S_2 E_{A\text{-}B,\,2} + \ldots + S_y E_{A\text{-}B,\,y} + \ldots + S_Y E_{A\text{-}B,\,Y} \qquad (3)$$

2.3. Model of Evaluating Communication Performance

No model is currently available in the literature to measure pilot-controller communication performance. Hence, the goal of this study is intended to develop a model capable of evaluating communication performance between pilots and controllers. According to the definitions of communication error and performance, it is reasonable to assume that the performance of communication between parties A and B is a function of the number of communication errors made during the communication between both parties ($E_{A\text{-}B}$), as presented in equation (4). In equation (4), $P_{A\text{-}B}$ is an indicator that represents the performance of communication between parties A and B.

$$P_{A\text{-}B} = f\,(E_{A\text{-}B}). \qquad (4)$$

It is obvious that there exists an inverse relationship between P_{A-B} and E_{A-B}. We employ the formulation of the gamma function with theta being equal to two and alpha equal to one, $\Gamma(\theta=2, \alpha=1)$, as a vehicle to evaluate the communication performance. The chosen gamma function has a desired property of concave up and decreasing slopes. The function of P_{A-B} is formulated as follows:

$$P_{A-B} = f_u (E_{A-B}) = k_u / (k_u + E_{A-B}). \qquad (5)$$

In equation (5), subscript u indicates the authority of air traffic control under which the communication takes place. In general, u could be Ground, Tower, Approach, or Center. k_u indicates a parameter that represents the maximum number of communication errors that can be tolerated when a pilot-controller communication takes place under authority unit u. The model expressed in equation (5) has the following properties that are suitable for evaluating communication performance:

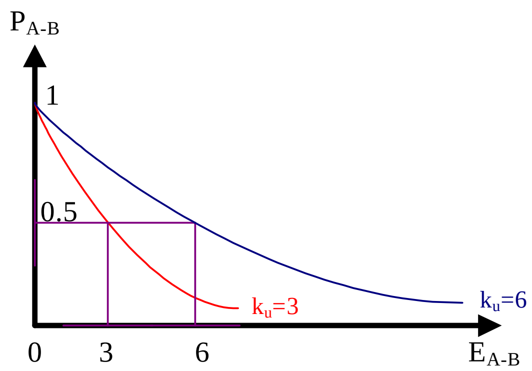
The maximum value of the performance indicator P_{A-B} is one, indicating the best performance meaning no errors made in a communication cycle. The worst performance occurs when P_{A-B} is close to zero and E_{A-B} is a relatively large number compared to k_u.

When E_{A-B} is equal to k_u, the maximum tolerable number of communication errors, P_{A-B} is equal to 0.5, which can be considered as a minimum acceptable performance level.

As illustrated in Figure 1, the relationship between P_{A-B} and E_{A-B} is nonlinear, with a steeper slope near the point of best performance and a flatter slope where the value of E_{A-B} becomes substantially large. This phenomenon indicates a decrease in the marginal effect of the number of communication errors with respect to the performance indicator, a meaningful phenomenon in performance evaluation.

Figure 1 shows that a lesser value of k_u is associated with a steeper slope near the point of best performance. This indicates that in a communication with a lower tolerable level of error is harder to reach the best performance.

Figure 1: Relationship between the performance indicator and the number of communication errors



3. EMPIRICAL ANALYSIS

3.1. Data

The communication related data analyzed in this research are based on seventy-three transcripts of pilot-controller transmissions from 2002 to 2004. The transcripts were reproduced by the Civil Aeronautical Administration of Taiwan because of their involvement in some incidents or accidents. However, not all parties included in the transcripts are key players of the involved incidents/accidents. All transcripts were carefully analyzed by researchers with expertise in radiotelephony phraseology. The elapsed time for each transcript ranges from five to fifteen minutes. For reasons of confidentiality, most identification in each transcript was deleted.

Additionally, a panel of ten senior supervisors in various air traffic control authorities was surveyed to elicit their opinions on the level of influence of communication errors on flight safety and the maximum number of errors tolerable in each communication.

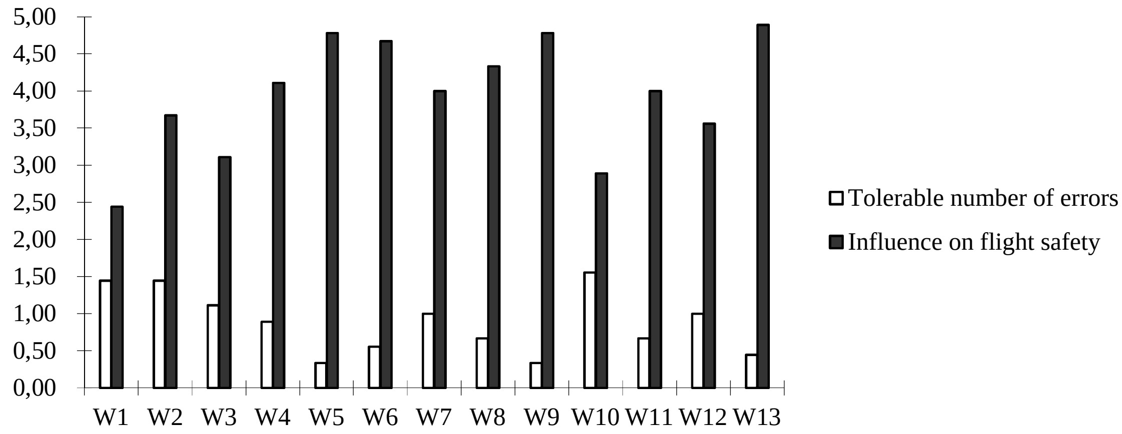
The subjects were asked to rate the level of severity of each type of communication content, on a scale from 1 (very *little*), 2 (*a little*), 3 (*neutral*), 4 (*severe*), to 5 (*very severe*). Nine out of the ten returned questionnaires were usable and included in the analysis presented in the next section.

3.2. Influence Levels and Maximum Tolerable Number of Errors in Various Communication Contents

Figure 2 illustrates the panel's opinions on the influence level and maximum tolerable number of errors in each category of the communication content. With respect to the influence level of communication contents, the average scores in the eight categories are greater than 4.0, the *severe* level, H_4 to H_9, H_{11}, and H_{13}. Communication contents related to aircraft maneuvers such as taxi, takeoff, and landing are generally included in these categories that would have *severe* to *very severe* influences on flight safety should communication errors be made. On the other hand, only two categories have average scores of less than 3.0, the *neutral* level, including communication establishment (H_1) and frequency change (H_{10}). The levels of influence of the remaining three categories (H_2, H_3, and H_{12}) are in-between.

The maximum tolerable number of errors in each content category has an inverse relationship with its associated influence level, as illustrated in Figure 2. For example, the three categories with the highest influence level (H_5, H_9, and H_{13}; 4.78, 4.78, and 4.89, respectively) have the least average tolerable number of errors, 0.33, 0.33, and 0.44, respectively. That is, in these three categories (takeoff, landing, and emergency) few errors can be tolerated.

Figure 2: Panel opinions on the influence level and maximum tolerable number of errors in each category of communication content

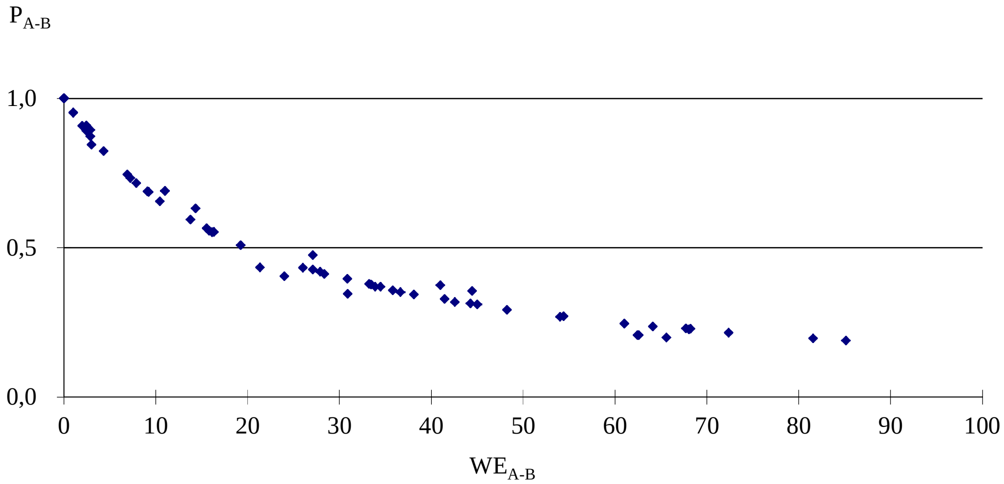


3.3. Measuring Communication Performance

All of the communication cycles in the 73 transcripts available to the authors were analyzed and the associated communication performance was calculated using the measuring model presented in equation (5). Communication cycles under the same transcript were combined and a performance indicator was calculated for each transcript. Figure 3 illustrates the distribution of the performance indicators. The mean value of the performance indicators is 0.55, which is slightly above the minimum acceptable performance level with P_{A-B} being equal to 0.50. The result implies that the overall communication performance based on the seventy-three transcripts is barely acceptable. It should be noted that the transcripts investigated in this research were associated with some incidents or accidents.

There are nine transcripts with performance indicators equal to 1.0, the best performance according to the developed model, which account for 12.3% of the sample. Additionally, 26 performance indicators (35.6%) fall into the interval between 0.50 and 0.99. The performance demonstrated that 38 of the transcripts falls under the minimum acceptable level, which is equivalent to 52.1% of the sample, another indication of the relatively low performance levels found overall.

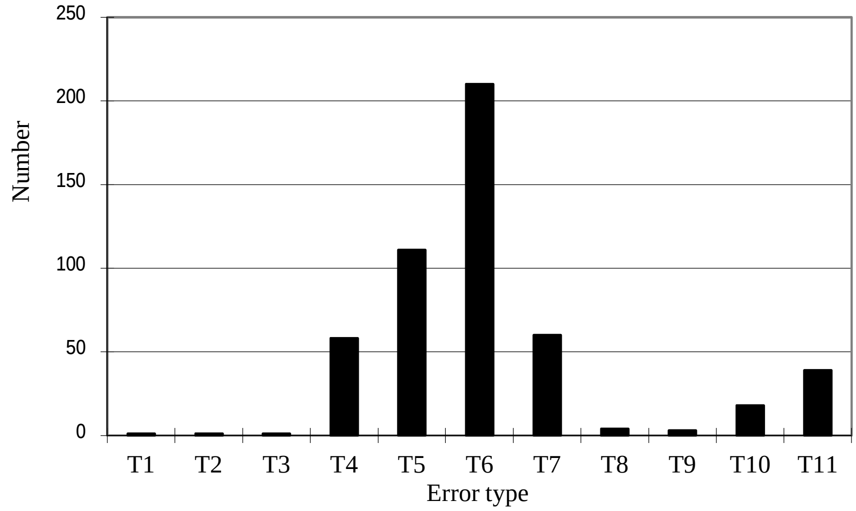
Figure 3: Distribution of performance indicators with respect to weighted number of errors across seventy-three studied transcripts



3.4. Distribution of Error Types

Figure 4 illustrates the distribution of the number of communication errors made in each error type. Among the 506 communication errors in the 73 transcripts under investigation, 210 (41.50%) of them can be categorized as type 6, incorrect read back/listening. Type 5, call-sign error, accounts for 21.34% (111) of the total error, which is followed by types 7 (incomplete clearance/information) and 4 (syntax error), with the numbers of errors being 60 (11.86%) and 58 (11.46%), respectively. According to the aviation experts surveyed in this research, the severity level of these four types of errors and type 1 (information not on time) can be considered relatively low. There are 440 (86.96%) errors in these five types. Errors categorized in other seven types (2, 3, 8, 9, 10, 11, and 12) are considered more severe, compared with the other five types. There is no error in type 12 and this number is not shown in Figure 4. Among the 66 errors with a relatively high level of severity, 39 (7.71%) can be categorized into type 11, incorrect phraseology, and 18 (3.56%) into type 10, no reply. Other types with severe influences contain only few errors.

Figure 4: Number of communication errors made in each error type



4. DISCUSSION AND CONCLUSION

Efficient and appropriate communication between pilots and controllers is a major determinant of flight safety. While communication barriers do exist, little has been done to quantitatively measure communication performance between these two major players in the aviation industry. The only available research in the literature that measures pilot-controller communication errors defines two types of communication errors: mishearing and not responding (Skaltsas et al., 2013). The present research identifies 13 types of communication contents and 12 types of communication errors between pilots and controllers from the prospective of radiotelephony phraseology. It also sets up a mechanism to measure the communication errors and develops a model to evaluate the communication performance that considers both the number of errors and the severity of the communication contents. Empirical data from 73 transcripts of pilot-controller transmissions are used to validate the proposed measuring model.

The proposed model for communication performance measurement is useful for several parties. Firstly, such a performance index includes information of the number of errors and the severity of communication contents, and may allow ATC authorities to better evaluate the overall communication performance, which provides a bigger picture than counting of individual errors. Secondly, if the identity of the aircraft and ATCs included in the transcript can be released, the proposed model can be used to evaluate the communication performance with respect to any available segmentation, such as nationality, title, age, gender. This information is expected to be very useful for pilots and ATCs training.

Additionally, communication errors related to aircraft maneuvers are considered to have *severe* to *very severe* influences on flight safety and few errors can be tolerated in these contents. The empirical study conducted in this research indicates that 87% of the total communication errors under investigation can be included in the categories with a relative low level of influence on flight safety, while 13% have severe influence. Finally, the results of performance measurement indicate that level of communication performance in the examples under investigation is relatively low. Hence, measures to further improve pilot-controller communication are necessary to ensure flight safety.

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REFERENCES

- Clifford E. Noble II (2002) *Predicting the language proficiency of Chinese student pilots within American airspace: single-task versus dual-task English-language assessment*, Dissertation, United States International University, San Diego, California, US.

- Galster, S.M., Duley, J.A., Masalonis, A.J., and Parasuraman, R. (2001) 'Air traffic controller performance and workload under mature free flight: conflict detection and resolution of aircraft self-separation', *The International Journal of Aviation Psychology*, 11(1), 71–93.
- Grayson, R.L. and Billings, C.E. (1981) 'Information transfer between air traffic control and aircraft: Communication problems in flight operations'*, Information Transfer Problems in the Aviation System. NASA Technical Paper* 1875, 47-62.
- Metzger, U. and Parasuraman, R. (2001) 'The role of the air traffic controller in future air traffic management: An empirical study of active control versus passive monitoring', *Human Factors*, 43(4), 519-528.
- Monan, C. (1988) *Human factor in aviation operations: The hearback problem*, Report No. 177398, NASA Contractor.
- Morrison, R. and Wright, R.H. (1989) ATC Control and Communication Problems: An Overview of Recent ASRS Data. In R. S. Jensen (ed*), Proceedings of the Fifth International Symposium on Aviation Psychology*, 901-907, Columbus, The Ohio State University.
- Rakas, J., Yang, S. (2007) Analysis of multiple open message transactions and controller-pilot miscommunications. *Seventh FAA/EUROCONTROL Seminar on ATM Research and Development,* Barcelona.
- Shannon, C. and Weaver, W. (1949) *The mathematical theory of communication,* The University of Illinois Press, Urbana, USA.
- Skaltsas, G., Rakas, J., and Karlaftis, M.G. (2013) 'An analysis of air traffic controller-pilot miscommunication in the NextGen environment', *Journal of Air Transport Management* 27, 46-51.
- Tsai, W.L. (2009) 'The role of language in radiotelephony communication: The perspective from pilots and controllers*. English Education and English for Specific*

Purposes, The Crane Publishing Co., London.

- Wiersma, E. and Mastenbroek, N. (1998) ‘Measurement of vessel traffic services operator performance’, *AI & Society* 12, 78-86.

INTEGRATION OF LANDSIDE PROCESSES INTO THE CONCEPT OF TOTAL AIRPORT MANAGEMENT

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ABSTRACT

Total Airport Management is a relatively new concept for a comprehensive optimization of airport processes. It is based on enhanced information sharing and communication among all stakeholders as well as on extended and improved forecasts of airport processes. The following paper describes a general concept for integrating landside passenger processes into Total Airport Management. It explains how landside stakeholders can be included in real collaborative decision making, in particular functionalities and Human Machine Interfaces of a prototypical TAM-compatible Passenger Management implementation called “PaxMan”. As a result of the improved linking of airside and landside processes, it is shown how airport stakeholders and passengers can benefit from this integration and from proactive airport operations.

Keywords: Total Airport Management, airport landside, passenger process, passenger flow prediction, terminal management, situation awareness

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1. INTRODUCTION

With a constantly growing air traffic it becomes more and more clear that airports represent a major bottleneck for the air traffic system (European Commission, 2011). The performance goals for airports set by the High Level Group in their "Flightpath 2050" accordingly are very ambitious (European Commission, 2011). In order to achieve those goals, new infrastructure cannot be the sole solution as it not only implies immense investments together with long lead times, but also will be impossible in realization in numerous cases. The focus consequently has to be set on efficient use of existing infrastructure with optimized airport operations. A lot of research has been done on single processes already and many improvements have been made in this area (ASD, 2010). However, optimization of single processes only will not be sufficient to meet above mentioned goals. Great potential is still lying in the integration of various separate airport processes and there is need for joint improvements and collaboration. Airport Collaborative Decision Making (A-CDM) was a first step in this direction and its great success underlines the benefits of looking at the airport as a whole. A-CDM introduced a new and enhanced way of information sharing among airport stakeholders leading to a reduction of delays (Sinz and Kanzler, 2012). However, A-CDM has a clear focus on the airside and does not consider landside processes or landside stakeholders. Interdependencies between airside and landside need to be addressed as they are manifold and striking. It is obvious that passengers are not able to fly without a plane ready for departure. On the other hand the airplane will not depart without passengers as a rule. The reasons for delayed or missing passengers are increasing with e.g. new security measures, stricter immigration procedures or higher number of delayed transfer flights. It is hence important to not only improve landside processes but also to integrate and synchronize them together with airside processes in order to optimally advance the overall airport system.

Total Airport Management (TAM) introduces a concept where landside and airside are closely linked. Enhanced information sharing and communication among all stakeholders throughout an airport as well as extended and improved forecasts of airport processes are core elements of this concept (Günther et al., 2006). It is expected that TAM is able to improve the overall performance of an airport and consequently to reduce the overall operating costs and the environmental impact. With regard to the landside the passenger comfort can be enhanced by smoother process flows with less waiting time and less delays.

This paper aims at introducing the concept of Total Airport Management from a landside perspective and at presenting new developments for the landside both conceptual and prototypical including several support tools useable within a TAM environment. For better understanding, the general concept of Total Airport Management will be illustrated in the next chapter. Thereafter, the focus is shifted on the landside aspects and the key elements of a TAM landside are explained more detailed. This is followed by an exemplarily description of a first realized implementation in chapter 4. The benefits and expected results thereof are subsequently presented and the paper ends with a short conclusion.

2. THE GENERAL CONCEPT OF TOTAL AIRPORT MANAGEMENT

The concept of Total Airport Management was originally introduced by DLR and Eurocontrol in 2006 and has been under development since (Günther et al., 2006). The aim is to improve the cooperation of the various airport stakeholders and with it to advance collaborative and coordinated planning of airport operations. In addition, the reduction of delays is one of the major goals as well as a more efficient and more effective resource management for the airport as a whole. The prediction of events and possible responses at an early stage presents another important element of TAM (Depenbrock et al., 2011).

The project “Total Airport Management Suite” (TAMS) was launched to further develop the initial TAM approach and to foster future industrial solutions addressing parts of this new management philosophy. TAMS[2] is a research project funded by the Federal Ministry of Economics and Technology based on a decision of the German Bundestag. As basis for the realization of above mentioned goals several requirements need to be fulfilled. According to the operational concept document of the TAMS project (Depenbrock et al., 2011) those requirements i.a. are:

- enhanced situation awareness,
- transparency of processes,
- a commonly agreed plan,
- a common set of data, and
- decision support.

As a method for indication of airport performance the introduction of central Key Performance Indicators (KPIs) is regarded as necessary. To complete the

[2] The TAMS project partners are: Siemens AG, Deutsches Zentrum für Luft- und Raumfahrt e.V., Barco Orthogon GmbH, INFORM GmbH, Flughafen Stuttgart GmbH and as associated partner ATRiCS Advanced Traffic Solutions GmbH & Co. KG.

requirements for TAM, post-analysis and statistical methods should be available to enable system adaptions and improvements (Dependbrock et al., 2011). Next to those conceptual requirements also some general ones need to be addressed before implementing a TAM system at an airport. Most importantly the compliance of all stakeholders involved has to be ensured and a legal basis has to be developed. In order to ensure fairness during the TAM processes for all stakeholders, some form of regulation like a merit-rating system needs to be established (Günther et al., 2009).

2.1. Stakeholder in the Concept of Total Airport Management

Generally a stakeholder at an airport can be every person or institution who is involved in or affected by airport operations. This definition also includes for example airport neighbours disturbed by noise. In the context of TAM, however, the number of stakeholders is limited to those involved in actual airport operations, namely

- airport operator,
- airlines,
- air traffic control (ATC),
- ground handlers,
- security authorities or service providers as well as immigration authorities

Those five parties (combining security and immigration) are each identified by different and partly conflicting interests in combination with different states of dependence. Airlines and airport for example clearly differ in the favoured length of spare time spent by passenger in the terminal. Ground handlers are likely to be contractually more dependent on the airline than the other way around. For the decision making processes in the framework of TAM this aspects needs to be addressed in the context of data and process ownership as well as for last decision right (Depenbrock et al., 2011).

2.2. Enhanced Information Sharing and Gathering as Basis for Total Airport Management

For best possible decision making the most essential requirement is reliable and up-to-date information. All stakeholders hence need access to all information relevant for their operations implying that all information has to be shared among all stakeholders as far as feasible with regard to privacy regulations. For the range of data collection A-CDM is seen as basis but needs to be enhanced with data provided by integration of different support tools like an arrival or departure manager providing for example more precise timestamps due to new calculations taking into account all stakeholders' restraints at the same time. The time frame of the collected data today has to be extended by predictions to enable accurate forecasts for the whole day of operation (Depenbrock et al., 2011).

2.3. APOC – A Central Element of Total Airport Management

The Airport Operation Centre (APOC) presents a platform for representatives of all stakeholders – so-called agents – to communicate, exchange information and to work collaboratively on upcoming problems. Necessary information, including alerts, is displayed on a video wall as well as on special HMIs at the agent working positions (Depenbrock et al., 2011). An APOC can be realized as a central room for all agents or may just be a virtual connection between the stakeholders' separate operations centres (Günther et al., 2006).

2.4. Collaborative Airport Planning in the Context of Total Airport Management

Collaborative Airport Planning (CAP) constitutes another integral part of the TAM concept. Main characteristics are negotiations to solve operational deviations or problems among all agents concerned and the co-ordination of a commonly agreed plan, named Airport Operations Plan (AOP). Consequences of alterations of the current AOP can be tested with so-called What-if probing and all agents concerned can then negotiate the best commonly agreed solution based on those results. However, the last decision right remains with the process owner (cf. chapter 2.1).

2.5. Key Performance Indicators as Important Characteristics for Airport Performance

To evaluate the adherence of current and planned airport operations to the AOP and agreed performance goals suitable measures are needed. Therefore, parameters that allow for a performance based management and for an advanced controlling of an airport have to be defined. In the context of ATM, the International Civil Aviation Organization (ICAO, 2009) as well as Eurocontrol with the European Operational Concept Validation Methodology (E-OCVM) (EUROCONTROL, 2010) define the two terms Key Performance Indicators (KPIs) and Key Performance Areas (KPAs). Whereas Key Performance Areas define performance subjects to categorize different broad areas related to high-level ambitions and expectations, KPIs are a means to measure past, current and expected performance levels by expressing them quantitatively. To categorize performance subjects ICAO defines 11 KPAs: safety, security, environmental impact, cost effectiveness, capacity, flight efficiency, flexibility, predictability, access & equity, participation & collaboration and interoperability. Several projects (e.g. (ICAO, 2009), (SESAR consortium, 2006) or

(Performance Review Commission/EUROCONTROL, 2009) specified KPIs in relation to these KPAs but only with focus on airside processes.

3. LANDSIDE PROCESSES IN THE GENERAL CONCEPT OF TOTAL AIRPORT MANAGEMENT

Major forecasts all predict a significant growth in the number of passengers for the next decades (e.g. (Airbus, 2010)). The increasing number of passengers especially in combination with increasing security and immigration measures will cause severe difficulties for landside processes at status quo level. The development of methods for holistic landside improvements, like new support tools for passenger flow as an extension of discrete resource management systems common today, will hence become necessary. The next subchapters present one possible solution to improve handling of passenger traffic on the landside. It is presented in the context of TAM in order to value the close link between airside and landside and to underline the importance of a holistic airport operations concept. While some of the introduced innovations might be implemented by themselves, the complete benefit will only be obtainable by applying the concept of Total Airport Management as a whole.

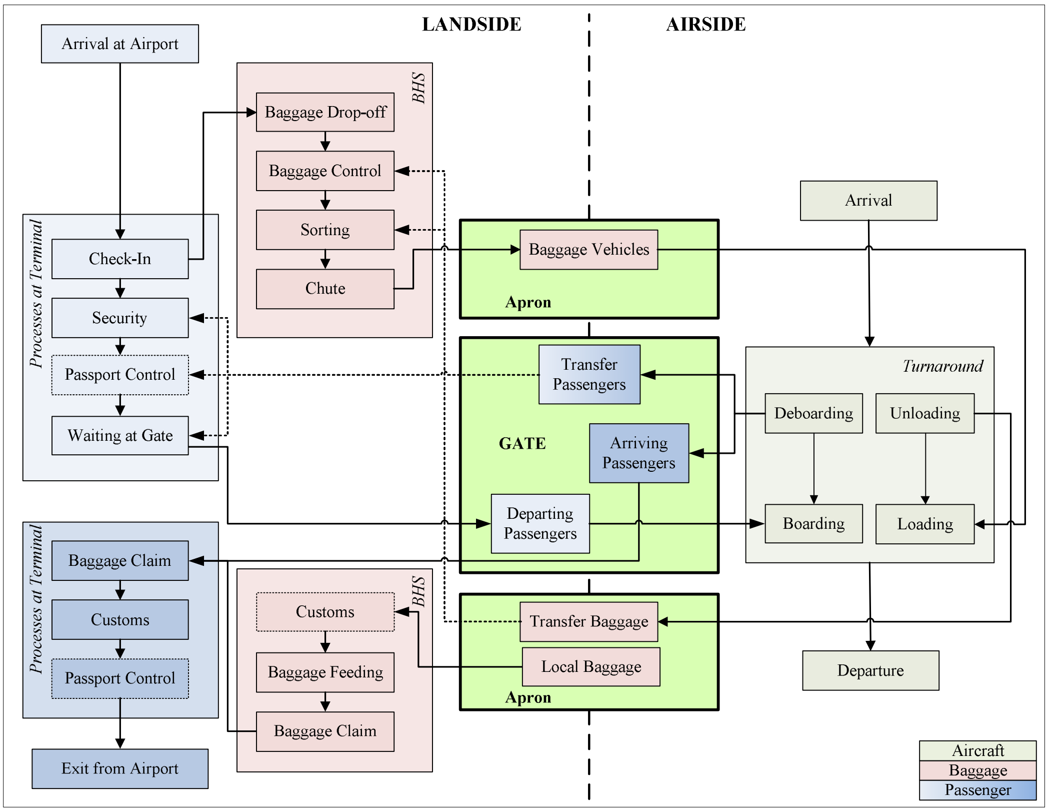
3.1. Definition of Relevant Landside Processes

In the framework of this paper the *landside of an airport* is defined as terminal area and includes all passenger processes from arrival at the airport until boarding the aircraft. To reduce complexity, baggage processes are at the moment only included as far as the baggage is still in possession of the owner, i.e. until drop-off at check-in counters or self-service kiosks. The same applies to intermodal airport connections, which are considered only as input for arrival time distribution. Figure 1 presents an overview of the major processes occurring on the landside. As all processes and the order of processes can vary from airport to airport all descriptions in this paper are based on a generic airport model and might have to be adapted to fit a specific airport. Additionally, depending on various factors such as destination of the flight, passengers may not have to undergo all processes. However, mandatory for all passengers are the processes check-in, security and boarding.

3.2. Determination of Landside Stakeholders

The process landscape for the airport landside is complex due to the large variety of processes and the unpredictability of exact passenger behaviour. The high number of different stakeholders involved in the processes additionally adds intricacy. Knowledge as well as information is partly restricted to process owners and thus a holistic and yet detailed overview of the landside proves difficult. Depending on the airport, different stakeholders will be represented like airport operator, airlines, ground handlers, different police forces, security service providers, custom authorities and immigration authorities. Optimally the intermodal connections of the airport are included too, adding i.e. local public transport providers, railway companies or road authorities. Table 1 gives an overview of the most common correlations between stakeholders and main landside operations including interferences. The process chain for baggage is combined under the term "baggage" due to previously mentioned complexity reasons.

Figure 1: Overview of Landside Processes at an Airport



With so many stakeholders in place there is a high amount of conflicting goals. While for private companies as well as (most) state-owned companies profit will present the main target, authorities like police forces will see other priorities und would rate e.g. security as aim number one even at the risk of higher cost. In doing so, state police forces as autonomous stakeholders will have a stronger position as, for instance, a security service provider dependent on a follow-up contract. The main challenge on the way to good collaboration among the different stakeholders is to overcome these different initial positions by proving that collaborating on overall improvement of the system will lead to benefits for each participant.

Table 1: Common Correlations between Stakeholders and Main Landside Operations

	Airport operator	Airline	Ground handler	Police forces	Security service provider	Custom authorities	Immi-gration authorities
Check-In	O	X O	X				
Security				X O	X		
Passport Control	O	O		X			X
Boarding	O	X O	X				
Baggage	O	O	X O	X		X	
Customs				X		X O	

X: process ownership
O: infrastructure ownership

3.3. Necessary Landside Information

The goal in TAM for the landside is on the one hand to enable enhanced collaboration among the different stakeholders and on the other hand to provide further and more reliable information on passenger processes for all landside stakeholders as well as for the airside linking. In contrast to the airside, the landside has one major disadvantage: planes have a known trajectory and are traceable, passengers not. Even if it would be technical and economical possible to equip passengers with traceable sensors, there are various legal constraints. Hence, at least for the near future, it will not be possible to gain information on the exact location of all passengers and thus there is no information on their individual arrival time at process stations at the airport. All data available on passengers is in most cases restricted to airlines (and in some countries to the immigration authorities) and consists of booking and check-in information. This implies that with online-check-in, a passenger is often registered at the airport for the first time during boarding. This complicates any forecast of passenger arrival times at the gate or previous process stations. First improvements are on their way with some airports introducing additional boarding pass scans at passport or security control allowing at least registering passengers at an earlier stage. New technologies also enable the calculation of waiting queue lengths allowing for more valuable information.

As a remedial measure improved and advance information could be gained from a new research prototype support tool suite called PaxMan (Passenger Manager) of which a more detailed description will be presented in chapter 4. Required as necessary data input, however, are the following:

- Information about resource allocation of process stations, such as planned opening and closing times,
- Information about actual situation throughout the terminal, such as waiting times and waiting queues at process stations,
- Process flows of passengers through terminal (modelling for purpose of forecasts).

Major output timestamp of the PaxMan is the newly introduced Estimated Passenger at Gate Time (EPGT) as the final landside timestamp. Synchronization with the airside process chain is achieved by aligning this EPGT with the Target Off-Block Time (TOBT). Delays in the EPGT will hence lead to the adaption of the TOBT according to the landside delay and vice versa.

3.4. Introduction of Landside Key Performance Indicators

Key Performance Indicators are measures to evaluate the performance of processes or the achievement of defined goals in such a manner that the past, present or expected future is expressed. This implies a need for reliable definitions of such indicators to obtain serviceable and required measures. The planning of operations at airports starts with a rough planning very early, for example on the basis of seasonal flight schedules half a year before the day of operations (day-of-ops). These plans are constantly adapted and enhanced with further information until the day before the day-of-ops. During the day-of-ops performance parameters are used to adjust the planned operations to the actual situation. One major aim of TAM is to prolong the timeframe for such information. This means that not only the actual situation is available for the assessment of the situation but also the expected development. Therefore, performance parameters should also be able to take into account a timeframe covering a few minutes up to several hours in advance. In general selected performance indicators should follow the SMART criteria: KPIs have a Specific purpose, are Measurable, Relevant for the process improvement, Time-related and the defined goal is Achievable (ICAO, 2009).

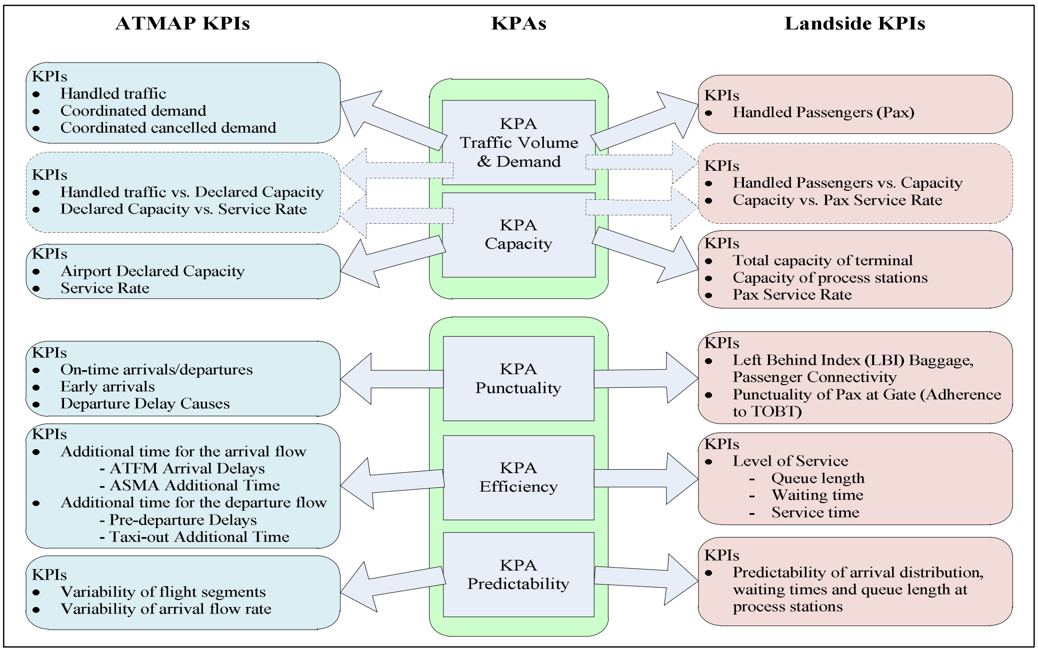
As stated before (section 2.5) in the context of ATM several definitions for helpful key performance indicators have been made. Nevertheless, they are focusing on airside processes and therefore are not transferable one-to-one but provide a good basis for the development of landside performance indicators. ATMAP (Performance Review Commission /EUROCONTROL, 2009) was one of such projects launched by the Performance Review Commission (PRC) developing KPIs for the following five key performance areas (KPA):

- traffic volume and demand,
- capacity,
- punctuality,
- efficiency,
- predictability.

ATMAP developed several KPIs within these areas taking into account the airport system as a whole, regarding several airport stakeholders and without accusing stakeholders contributing to the achieved performance. Therefore first possible landside KPIs are derived from these KPIs (Performance Review Commission/EUROCONTROL, 2009), as shown in Figure 2.

All stakeholders at an airport intending to collaborate have to select or rather agree on indicators suitable for their intention. Hence, indicators can vary between several airports, but the above provided key performance indicators are rather general and should be more detailed in their respective application and exact dimension.

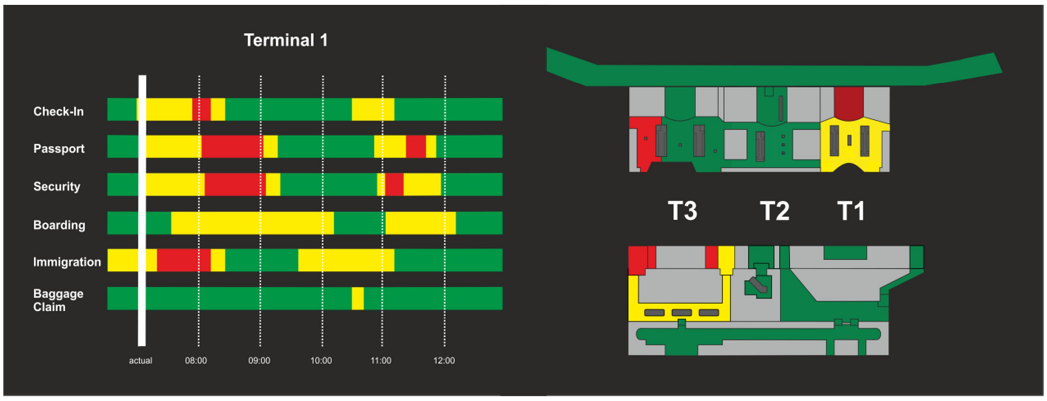
Figure 2: Possible Landside Key Performance Indicators



3.5. Possible Landside Data Presentation on a Joint Video Wall or Agent Working Position

The video wall in the APOC has the task to provide the different agents with a common overview of all information necessary for collaborative and envisaged airport planning especially to generate common situation awareness. In order to guarantee good recognisability and comprehension of information an ergonomic interface design has to be applied for the setup. For further material on this subject, for example refer to (Jipp et al., 2011). With regard to landside aspects it has to be ensured that the status of processes in the terminal is observable, at best on process level but at least combined on terminal level. This information should include the actual as well as the predicted situation for the upcoming hours of operation. Possible implementations of this information in form of a colour coded bar chart or terminal layout are presented in Figure 3. In addition, the video wall should have some reserved space e.g. to accommodate video surveillance images or more detailed information presentation than the aggregated view always visible (Depenbrock et al., 2011).

Figure 3: Possible Landside Elements for a TAM Video Wall Displaying Actual and Predicted Terminal Process Status



Next to the combined video wall all agents have special HMIs at their working positions accommodating specific information needed for their role and responsibility. Those include besides the information overview the installed assistance systems hence allowing access to more detailed information necessary for the decision making process. The working positions also provide for an input facility for the handling of support tools.

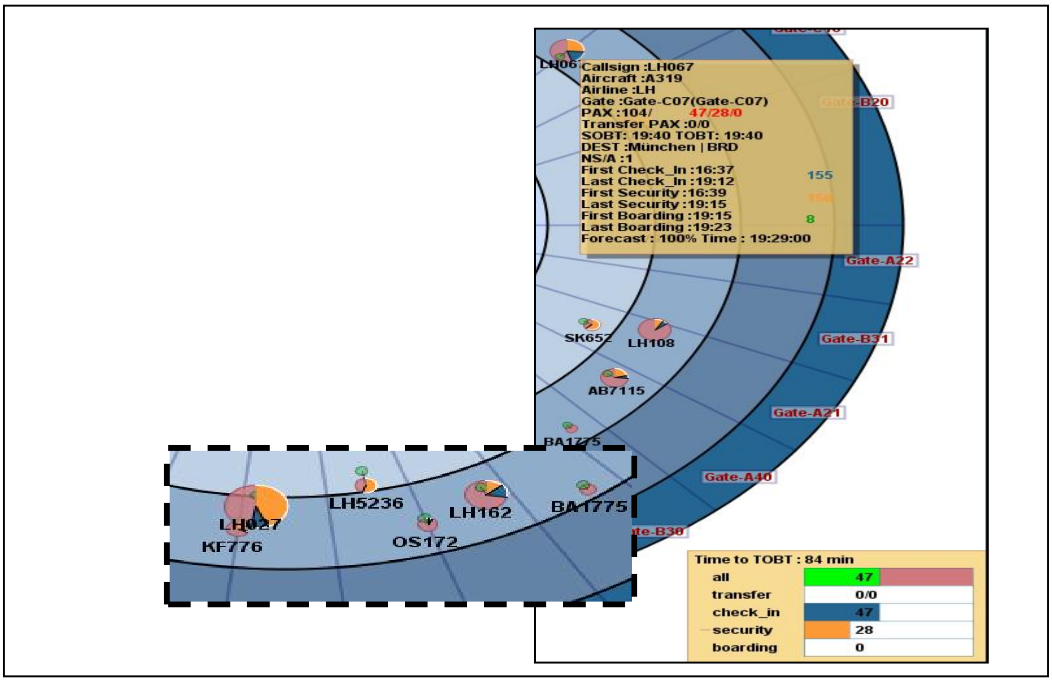
4. PROTOTYPICAL IMPLEMENTATION FOR THE INTEGRATION OF LANDSIDE PROCESSES INTO THE CONCEPT OF TOTAL AIRPORT MANAGEMENT

The support tool developed within the above-mentioned TAMS project for the integration of landside processes into the concept of Total Airport Management is called Passenger Manager (PaxMan). It is a tool suite to assist the management of passenger processes in the airport terminal. It supports terminal management by the airport operator and furthermore is able to provide aircraft operators and ground handlers with helpful information and functionalities for efficient passenger handling. The PaxMan is able to predict the last passenger at the gate for each flight defined as “Estimated Passenger at Gate Time” (EPGT) (Depenbrock et al., 2011) by monitoring all relevant passenger processes based on the actual situation in the terminal. Three modules of the PaxMan suite are exemplarily highlighted in the following sections.

4.1. Passenger Radar

The Passenger Radar (PaxRadar) is a tool to visualize a large amount of information in a compact layout and has the goal to improve overall situation awareness concerning the passenger status throughout the airport. As illustrated in Figure 4, it shows the actual state of all planned flights and their related passengers at an airport within the upcoming day of operation.

Figure 4: HMI of PaxRadar

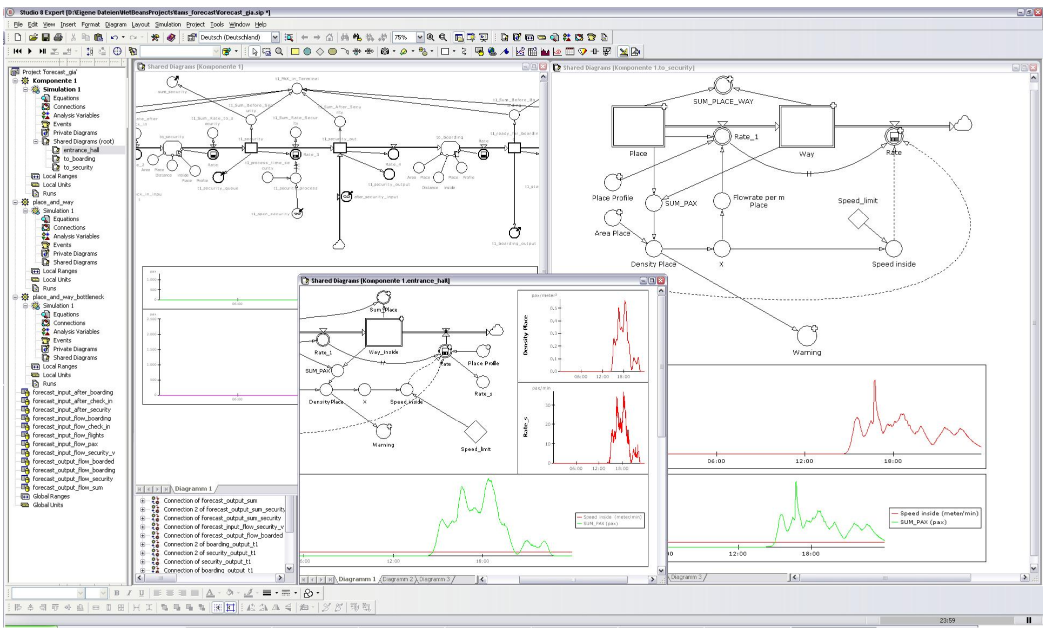


Each circle represents one flight and the size of the circle correlates with the number of passengers booked for this flight. The position, where the flight is placed on this radar display represents a combination of the planned gate, the airline, the aircraft, the destination (city or country) and the difference between the actual time and the Off-Block-Time of this flight. Each circle comprises three circular segments representing the number of passengers checked-in (blue), the number of security checked passengers (orange) and the number of boarded passengers (green). When pointing on a flight represented by a circle, detailed information like destination, airline or for example transfer passengers of the chosen flight is shown (for more details see Figure 4). An overview of the status of this flight's passengers is provided also showing the respective rate of completion at major process points (check-in, security and boarding). This especially supports a judgment whether passengers might reach a flight on time. The information gathered and shown in the PaxRadar is also used for the forecast presentation. The PaxRadar provides an overview of the actual situation in the airport terminal in order to increase the situation awareness. It also shows further information like the EPGT generated by the forecast as a small green circle.

4.2. Forecast Functionality

Another important capability of the PaxMan Suite is the forecast functionality. Visually integrated in the PaxRadar described above a forecast of the expected status of passengers in relation to their flights is provided. The forecast is responsible for computing the EPGT.

Figure 5: Forecast Model



The forecast functionality is specifically designed on principles of a macroscopic system dynamics simulation (see Figure 5). Depending on the actual planned TOBT for each flight (or SOBT if the TOBT is not yet existent) this module allows for a very quick and yet reliable forecast how many passengers will be at the gate on time and when the last passenger can be expected which correlates to the EPGT. The system dynamics simulation is operated as a service and automatically reacts to flight plan updates. As soon as an update is filed to the PaxMan a new forecast run is triggered in order to examine the differences and consequences. The new estimates are also based on actual status of all landside and airside systems, resources and actual passenger status.

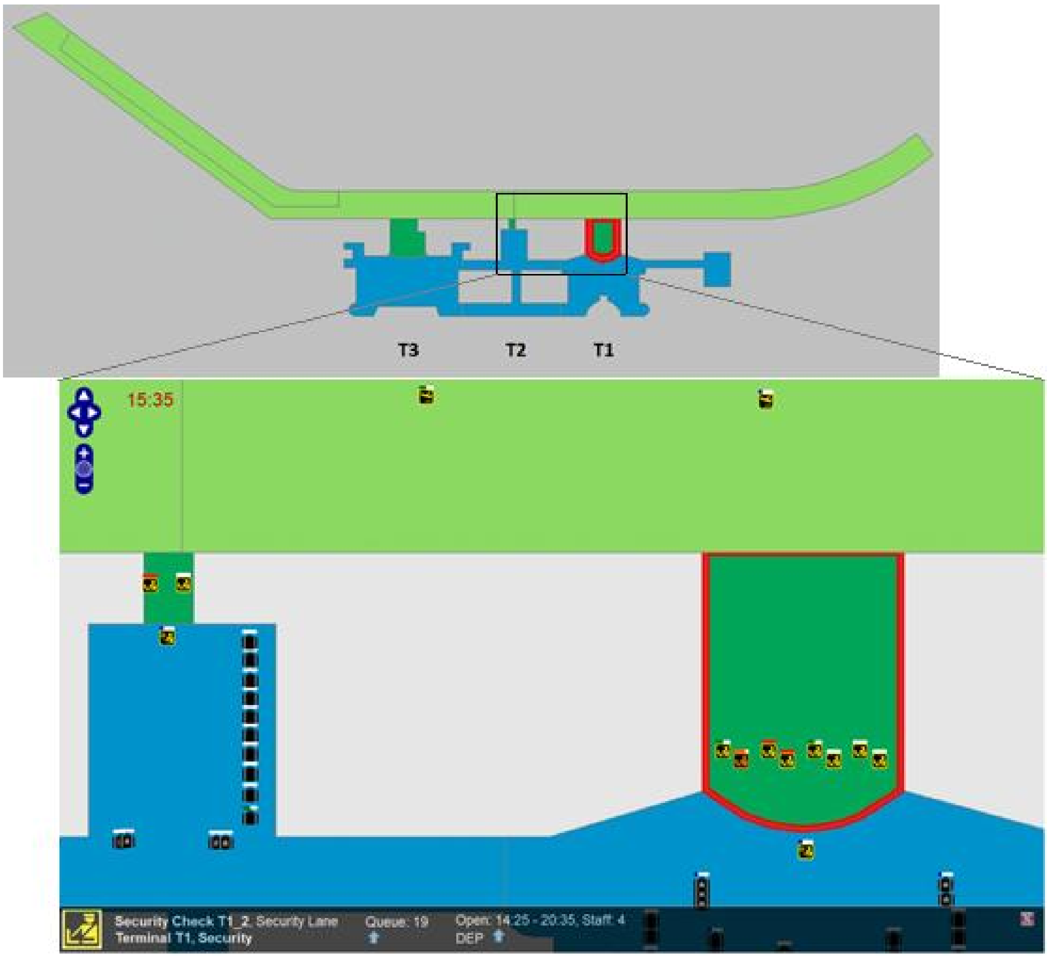
The results of the forecast simulation are displayed in the PaxRadar and can also be used for direct integration with airside management systems in order to establish proper synchronization and fostering a proactive airport management.

4.3. Paxwall

Another part of the graphical user interface (GUI) of the PaxMan is called PaxWall and is illustrated in Figure 6. Aim of the PaxWall is also improvement of the situation awareness in a Total Airport Management environment. Dependent on the application area of a user, the base GUI can be adjusted in the degree of displayed detail of information and possibilities for a user to interact. The GUI can be used on different devices like a standard desktop monitor with a high degree of user interaction or on a video wall with abstract information display without user interaction as well as on mobile devices, such as smartphones or tablets. To easily achieve this universal display a platform independent and web-based visualization has been implemented. The objective was to provide a well-engineered web application for user. The usage of a single web page avoids the feeling of a complex program structure. All necessary information completely fits on one monitor so a user has no need to scroll. Additional or updated data is loaded dynamically from the server and is automatically integrated into this web page without completely reloading it.

The basic GUI of the PaxWall is a smoothed map of the airport terminal of the generic airport model used in the TAMS project. The terminal map is based on OpenLayers. OpenLayers is an open source client side JavaScript library to create interactive web maps, viewable in nearly any web browser (Hazzard, 2011). The user interaction capabilities (e.g. zooming, panning etc.) are similar to the well-known Google Maps, which will increase usability and acceptance of users.

Figure 6: PaxWall – Overview of Airport Status



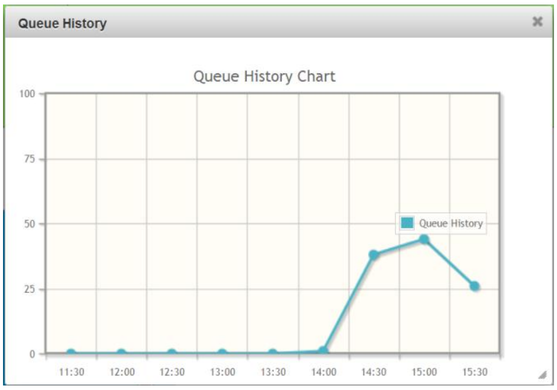
The colour model separates four airport process types: blue for check-in, green for security, light green for gates and light blue for baggage claim. The colour coding also provides for an optical alerting functionality. The alerting is based on the queues calculated by another module within the PaxMan. For each task station KPI thresholds can be defined according to IATA level of service standards (levels A to E) and local requirements. The alerting mechanism itself is a filter on these thresholds. If the queue at a task station is smaller than level A, the alert-label 'low' is set to this task station. For visualization a dark blue colour represents this status. If the queue is between the thresholds level D and level E, the task station enters a "warning" state (orange colour). Alert label 'fatal', represented by a red colour, is set to the task station if the queue exceeds the threshold of level E. There is also a higher aggregated variant of the alerting mechanism. An airport is separated into terminals (e.g. Terminal 1) and terminal areas (e.g. security checkpoint in Terminal 1). If a defined maximum queue length of the task stations in a certain (terminal) area exceeds a threshold, alert labels as defined above are set to the corresponding terminal area. This basic visualization is used for the video wall in an airport operation control centre (APOC). Figure 6 shows an example with a bottleneck at the security area of Terminal 1. The refresh rate for the alerting layer can be adjusted. Visualization for an agent's working position with a standard desktop monitor is designed with maximal information density and possibility for user interaction. The terminal map can be intuitively zoomed and panned. The zoom levels, however, differ in the level of detail displayed. The first zoom level is reduced to the basic terminal layout. Queue alerting is represented by the maximum queue size for all queues per terminal area and is persistent throughout all zoom levels.

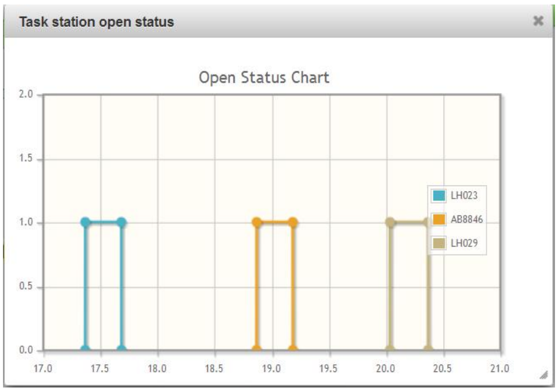
By zooming in more details are provided. As soon as the second zoom level is displayed, all available task stations are displayed as markers in the terminal map. Individual icons have been designed for each task station (check-in, security lane, border control and gate). All markers are clickable to gather further details about the respective task station. A clicked marker is highlighted. A bar above these icons visualizes the queue alerting for each task station. Four alerting states are available: blue for very low usage, green for keeping limits, orange for warning state and red for alerting state.

Figure 6 shows a zoomed map with details about the security lane 2 at Terminal 1 as a black overlay in the lower part of the screen. The task station icon, its name and category, its terminal and terminal area is displayed as static information. The dynamic part of the displayed data contains the actual queue size, the current opening status and time, the staff count operating at this task station and an opening reference.

By clicking on the blue arrows charts can be retrieved showing the queue history and the opening time blocks for the actual day (see Figure 7). The upper chart displays the queue length of a security lane over the past four hours. The lower chart shows the opening times for a gate for specific flights. The x-axis is the time displayed as a float value to get exact chart characteristics. The y-axis is the staff count operating that gate. Each time block represents exactly one flight.

Figure 7: Charts for Task Station Details (On the left: queuing history for a security lane; on the right: opening status for a chosen gate)





5. EXPECTED BENEFITS AND RESULTS

By integrating and synchronizing landside processes with airside processes the focus of airport operations is shifted more towards the passenger. The benefits are on two sides. First of all, it is the passenger who directly benefits from smoother flow of procedures at the airport combined with an improved punctuality, more reliable operations, reduced waiting times at process stations as well as better and earlier information. This results in an improved travel experience for the passenger. On the other hand also airport operators and airlines benefit from a better knowledge of the passenger's status. The PaxMan module described above provides better situation awareness about the passenger flow in the different functional areas of the airport, thus improving transparency. Especially the forecast functionality enables early response and even a KPI-based proactive management of resources. This helps to improve efficiency and optimized utilization of available infrastructure. The cooperative and coordinated planning of all stakeholders facilitates synchronized processes throughout the airport. This synchronization again fosters overall punctuality and also supports the complex airport operations especially in recovery from disturbances. Test runs of the integrated system showed good potentials for improving overall punctuality and passenger connectivity without increasing operational costs. To put it in a nutshell integration of airport airside and landside processes improves the passenger comfort and at the same time supports the airport stakeholders to improve overall operational performance and efficiency.

The integration and synchronization of airport passenger processes with aircraft oriented processes is an important improvement in airport operations. Interdependencies between the landside and airside are clearly targeted with the Total Airport Management concept. This integration could be implemented for the first time in a research prototype for passenger management in the TAMS project. First test results showed good potentials for an improved overall performance – especially in terms of punctuality and passenger comfort.

REFERENCES

- Airbus (2010),*Global Market Forecast 2011-2030*, Toulouse: Airbus.
- ASD (2010), *ACARE Goals Progress Evaluation*, Brussels: ASD.
- Depenbrock, F., Dr. Temme, A., Urban, B., Günther, Y., Helm, S., Neuling, D., Piekert, F., Schaper, M., Straube, K. (2011), *TAMS - Operational Concept Document - Part I*, Braunschweig: German Aerospace Center (DLR).
- EUROCONTROL (2010), *European Operational Concept Validation Methodology*, Brussels: EUROCONTROL.
- European Commission (2011), *Flightpath 2050 - Europe's Vision for Aviation. European Union*, Luxembourg: European Commission.
- Günther, Y., Inard, A., Werther, B., Bonnier, M., Spies, G., Marsden, A., Temme, M., Böhme, D., Lane, R., Niederstraßer, H. (2006), *Total Airport Management (Operational Concept and Logical Architecture)*, DLR & EUROCONTROL.
- Günther, Y., Werther, B., Schaper, M., Spies, G., Bruchseifer, R. (2009), *FAMOUS - Operationelles Konzept*. Braunschweig: German Aerospace Center (DLR).
- Hazzard, E. (2011), Openlayers 2.10 Beginenr's Guide. Packt Publishing, Birmingham.
- ICAO (2009), *Manual on Global Performance of the Air Navigation System*, Montreal: ICAO.
- Jipp, M., Schaper, M., Günther, Y., Papenfuss, A. (2011), Ecological Interface Design and its Application to Total Airport Management. *IEEE Conference on System, Man, and Cybernetics.* Anchorage, October 09-12.

- Performance Review Commission/EUROCONTROL (2009), *ATM Airport Performance (ATMAP) Framework - Measuring Airport Airside and Nearby Airspace Performance*, Brussels: EUROCONTROL.
- SESAR consortium (2006), *Air Transport Framework*, Brussels: SESAR consortium.
- Sinz, E., Kanzler, P. (2012), *Airport CDM Munich - Results 2011*, Langen: DFS Deutsche Flugsicherung GmbH & Flughafen München GmbH.

TRAFFIC RELATED REPRESENTATIVE AIRPORT CATEGORIES FOR TECHNOLOGY IMPACT EVALUATION

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Abstract

Technology impact evaluations in air transport require the specification of environment conditions, such as the traffic structure. Since a multitude of worldwide traffic situations exists, this paper presents a systematic approach based on cluster analysis that can handle the worldwide diversity, while ensuring to determine most relevant traffic situations. This is crucial for the universality and global relevance of evaluation results. The approach is presented for the application example of runway capacity evaluation, as part of which features of daily movement distributions of airports and the traffic mix as well as peak situations are quantified. The resulting representative airport and peak categories comprise a limited set of typical traffic situations worldwide that can serve as standard input for capacity-related evaluation, ensuring comparability and clarity.

Keywords: Airport, categorization, representative, air traffic

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1. INTRODUCTION

Evaluation of the impact of new technologies in air transportation is important to ensure an efficient transport system in the future. Moreover, it is crucial to determine this impact on a global level to cover a range of potential environment conditions faced and to evaluate whether a certain technology or concept proves its potential. The specification of environment conditions for these evaluations has a considerable influence on the results and needs to be pursued thoroughly and systematically. A major problem to be faced is the worldwide diversity in traffic conditions that has to be handled. It is not possible to cover each and every specific environment condition in impact analyses since this is computationally demanding. However, a reduction of environments to a few specific local ones is also not beneficial as it focuses on local peculiarities that do not reflect the global range of environments. Therefore, this paper provides a systematic approach to determine global representative environment conditions. Since the approach is application specific, runway capacity impact evaluation is addressed as an example.

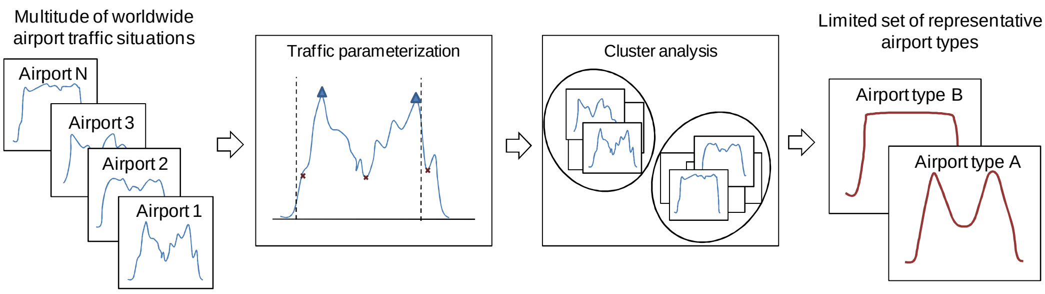
Evaluation of aircraft concepts in their operational environment, such as runway capacity analyses, and their impact created requires the traffic structure at an airport as one of the main environment inputs. This includes the daily airport traffic as well as traffic peaks that occur. The example of runway capacity impact was considered, since the runway system is one of the most constraining elements influencing airport capacity (Böck and Hornung, 2012). Böck (2013) focused on the evaluation of capacity impact of aircraft concepts based on selected real airport environments only. He mentioned the need of further addressing the diversity in traffic situations to ensure more generalized results. As explained above, selection of particular real airports is not the most favorable solution for assessments on a technological level since the specification of most suitable real airports is difficult and each real airport will incorporate peculiarities in the analysis process that influence the results. In order to evaluate aircraft concepts in a global perspective, a set of representative airport categories with distinct application-specific traffic characteristics could provide this desired input.

Before deriving individual categorizations of airports, existing ones were elaborated. A variety of definitions for airport categorizations can already be found worldwide. A review of existing categorizations was presented in Öttl and Böck (2011), along with a judgment of applicability of these categorizations for air traffic-related simulations and analyses. For these kinds of applications the quantified description of operational or traffic-related characteristics was found to be an important criterion. However, existing categorizations do not sufficiently describe traffic-related features, but rather contain qualitative descriptions or specifications related to passenger numbers only. This analysis already pointed out the need for application-specific airport categorizations based on similar traffic characteristics and not on passenger numbers or other qualitative features not related to the intended application.

In a first approach to address similarities in air traffic at airports, Öttl et al. (2013) presented an evaluation of worldwide airport peak situations for use in runway capacity analyses. By application of a cluster analysis, similar groups of traffic peaks could be determined and a representative limited set of peak situations could be specified. This idea of deriving typical worldwide traffic situations is extended in this paper and addressed on an airport level rather than for peak traffic situations only. The work of Öttl et al. (2013) only covered an analysis of air traffic peaks at airports. These were characterized by their traffic mix. However, it was already mentioned that a capacity impact analysis requires daily traffic structures at airports in addition to the peaks. Hence, in the current paper the focus is on the derivation of representative airport categories based on parameters describing the daily traffic characteristics at airports. Additionally, the cluster analysis process is further improved compared to previous work and the data basis further extended.

An overview of the process of deriving representative environment conditions (i.e. traffic-related representative airport categories in the application context) is shown in Figure 1.

Figure 1: Overview of the Approach to derive Traffic-Related Representative Airport Categories



Notes: Traffic characteristics at airports are parameterized and clustered. This reduces the multitude of airport traffic situations worldwide to a limited number of representative cases.

This systematic process identifies similarities in a multitude of traffic situations worldwide, which serve as the basic input. In order to pursue this, a cluster analysis is applied for which it is necessary to determine relevant parameters that describe the traffic environment. These parameters mainly depend on the intended application of the resulting airport categories. The cluster analysis results in a limited set of representative airport types, which enables a clear and comparable traffic-related analysis and can be considered as a standardized input.

The specification of relevant parameters to describe the traffic environment is not straightforward. Hence, this traffic parameterization is explained in detail in section 2, while section 3 outlines the cluster analysis process applied to determine an optimal number of groups of similar airports and peaks. Section 4 provides the resulting airport clusters for airport capacity related evaluations.

2. TRAFFIC PARAMETERIZATION

The cluster analysis incorporated in the presented approach requires a clear quantification and parameterization of the environment conditions of relevance. Hence, before traffic-related similarities in airports can be identified for the application example, it is necessary to determine appropriate similarity parameters that are of importance in this context and at the same time are suitable to characterize the differences in traffic features among airports.

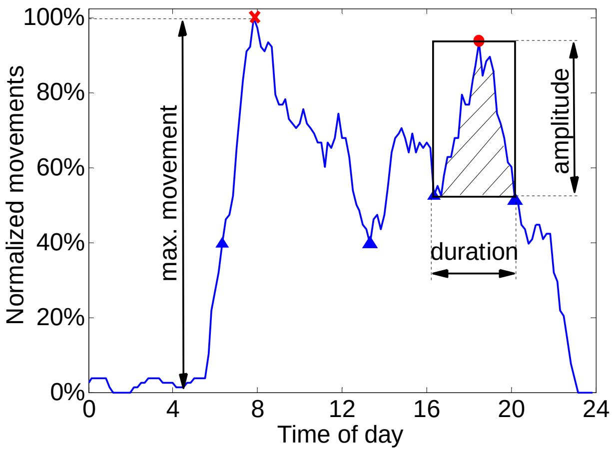
The main sources of parameters to be taken into account are the technology evaluation methods for which the resulting representative environment conditions are intended to be applied. On the one hand, parameters can be directly incorporated as a similarity measure for clustering in case the data basis for them is available and there is a clear way to determine them (e.g. percentage of heavy aircraft movements in one day). On the other hand, there are cases where one specific parameter cannot be directly determined or where several parameters are required to specify a certain situation (e.g. parameters that characterize the movement distribution in one day). In these cases new parameters or metrics can be defined. In the following, similarity parameters of importance for runway capacity related technology evaluation are discussed.

2.1 Traffic Parameters for Capacity-related Application

The methodology used for runway capacity impact evaluation is considered as given, being described in Böck and Hornung (2012). From this method the required input parameters characterizing the evaluation environment can be specified. General traffic parameter needs for runway capacity related technology evaluation were also mentioned in previous publications of this application context (see Öttl and Böck, 2011; Öttl et al., 2013). As mentioned earlier, both traffic peaks and daily airport traffic are considered in this approach. A further important element of the evaluation environment for capacity analysis is the runway system, i.e. the infrastructure. However, in this paper only relative traffic-related characteristics are considered, not taking into account infrastructure features. This decoupled assessment was also proposed by Böck et al. (2011). Nevertheless, an analysis of relevant infrastructure layouts on a global level is important for capacity analysis, but is independent of the findings in this work.

In Öttl et al. (2013) it was shown that peak traffic situations can show similarities across different types or sizes of airports, when considering the traffic structure in terms of the aircraft mix only. However, that analysis did not consider any information that describes the peak shape, which is also important to characterize a peak traffic situation. Moreover, peak situations can vary significantly during a one week period, depending on the type of airport. Therefore, it is advisable to take a whole week of scheduled traffic into account (see also section 2.2). To describe a peak situation, certainly the aircraft mix is incorporated as a main feature. Similar to the development in Öttl et al. (2013) 10 aircraft weight classes based on an analysis of maximum take-off weight of currently operating aircraft types (see also Figure 11 in Appendix) were incorporated as the parameters to describe the peak mix. Since arriving and departing traffic can show significantly different shares in a peak situation, it is important to distinguish between these two. The final set of similarity parameters for traffic peak situations also contains peak shape-related parameters. In an analysis of a variety of potential parameters regarding their suitability as a similarity measure the following three have been selected: peak duration in hours, peak fill factor and peak amplitude as percentage of the maximum peak at the respective airport. The three parameters are shown in Figure 2. The fill factor specifies the area under the peak in relation to the area of a rectangle, given by the minimum and maximum peak deflection. The peak amplitude is determined relative to the maximum peak at the airport to allow for a dimensionless assessment of airports of different movement numbers. The identification of a traffic peak in a daily movement distribution is performed by an automated algorithm, allowing for an analysis of a large amount of airports. The underlying steps are not explained further, since they would go beyond the scope of this paper. However, it should be mentioned that existing definitions of a typical peak situation (e.g. Standard Busy Rate in Ashford et al., 1991) do not play a significant role in this context. These are mainly based on passenger numbers or focusing on a period of an entire year rather than the daily traffic structure. To be able to incorporate a large amount of airports, peak detection is based on daily movement distributions determined from OAG flight data (OAG, 2008).

Figure 2: Illustration of Parameters to describe a Traffic Peak Shape



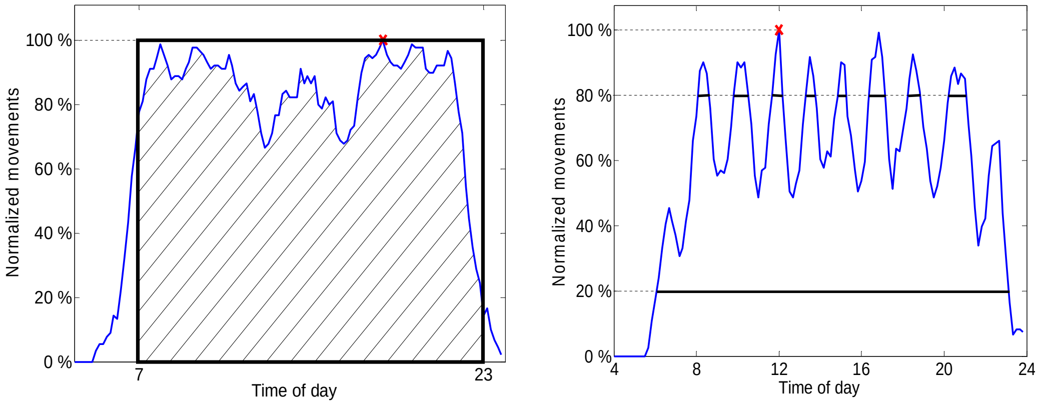
Notes: Triangles mark the start and end points of peaks, the red dot is a peak maximum and the cross marks the maximum peak at the airport.

Apart from peak traffic situations there are additional traffic characteristics of importance for capacity-related technology evaluation. First, the total daily traffic mix at an airport should be considered for an analysis. Therefore, the 10 aircraft weight classes are considered again. As a major difference to peak situations, the daily traffic does not require a differentiation into arrivals and departures, since both should be close to equal during one day of operation. The distribution of aircraft movements during one day should also be taken into consideration for a capacity-related airport categorization. From these distributions different characteristics can be identified, e.g. whether traffic peaks occur and how many of them. Moreover, periods of high traffic load can be determined. The parameterization of the daily movement distribution is an example for which no pre-defined clear parameters exist. Airport categorizations based on movement-related features have not been specified before. In an extensive study a multitude of parameters or metrics have been specified that characterize certain features of this daily distribution. By analyzing the suitability as a similarity measure, e.g. by clustering of a single parameter, and expert judgment, the number of parameters could be reduced to the most relevant that are explained in the following. In order to allow for an analysis independent of the actual absolute size of an airport, parameters referring to the number of movements were specified relative to the maximum number of movements at the respective airport.

The number of peaks (NP) states how often peak situations occur in the daily traffic characteristics. Besides determination of the number of peak situations in the total movement distribution, also the peaks in arrival and departure distributions are of interest for traffic-related investigations. The fill factor (FF) of the daily movement distribution is derived similar to the peak fill factor. It represents the area under the movement distribution graph in the time period from 7:00 to 23:00 (local time, LT), divided by the area of a rectangle given by the maximum movement number at that day at the respective airport (see hatched area share of rectangle in Figure 3, left). This fill factor allows an identification of airports with high total loads during the day and is a measure of how much of a fictitious movement limit is already used up. Of course, the significance of the fill factor would be highest when official capacity limits of airports were used. Unfortunately, these are not generally available for a large airport dataset. Hence, the maximum number of movements is a reasonable reference. Since for almost all airports traffic load issues arise primarily during the day, the fill factor was defined for a frequently used time period of day (7:00-19:00 LT) and evening (19:00-23:00 LT) (EC, 2002).

In contrast to the fill factor the parameter relative load (RL) provides information on the amount of time where flight activities reach a high number of movements. These are usually allocated to peak situations. Therefore, the time period of flight activities at or above 80% of the maximum movement number, resembling a high load condition, are determined and set into relation to the time period for 20%, which was specified as a general operating condition of low traffic load (see Figure 3, right). A low value indicates that only certain peak situations reach high load values, while a value close to 100% states that the airport constantly operates under high load conditions (compare also Figure 4).

Figure 3: Illustration of the Parameters Fill Factor (left) and Relative Load (right)

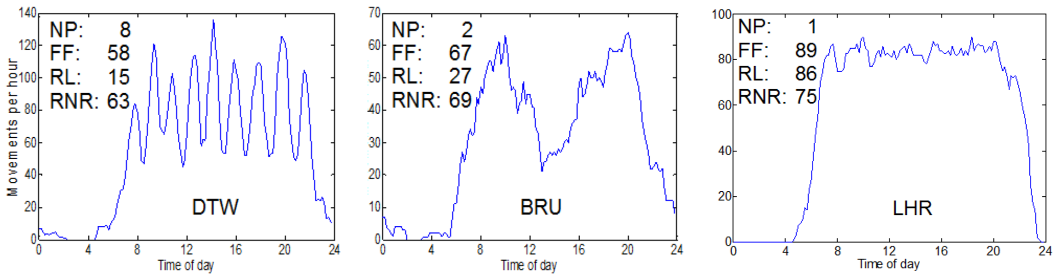


Notes: The fill factor is the ratio between the hatched area under the movement graph and the rectangle specified by the maximum number of movements (indicated as 100%). The relative load relates the duration in which flights occur at and above 80% of max. movements to a lower limit of 20%.

For determining the relative night rest (RNR) parameter the frequently used definition of the night time period (23:00-07:00 LT) is considered (EC, 2002). Analyzing this time period, the total duration in which the movement numbers are below 5 in 30min intervals is considered the night rest period, since movement numbers are significantly low (only few freighter or mail flights can occur). This duration is then set into relation to the total 8h night time period again. A value of 100% states that there are no significant movement numbers in the night period.

In order to illustrate the ability of the parameters described to characterize significant features of movement distributions, Figure 4 shows three very distinct airport examples along with their parameter values for a single day. It can be observed that peak number and the relative load are able to describe the peak characteristics, while the fill factor provides a value for how much of the daily distribution is "filled" to a limit. While the parameters mentioned describe day time features, the relative night rest finally provides information about the night time period, the latter of which shows only minor differences in the examples presented.

Figure 4: Three Examples of Significantly Distinct Daily Movement Distributions along with their Parameter Values



Notes: NP: number of peaks, FF: fill factor in %, RL: relative load in %, RNR: relative night rest in %.

2.2 Specification of Data Samples

The similarity parameters need to be determined for a large-enough dataset of airports for cluster analysis. This airport dataset shall contain a variety of airports worldwide that are of relevance for similarity assessment. Analyzing the ACI report 2007, it could be determined that 90% of worldwide passenger traffic is accommodated at only 302 airports worldwide. In comparison, 473 airports account for 90% of worldwide aircraft movements. Hence, a reasonable airport dataset was specified by the intersection of the two specifications, resulting in 287 airports. This dataset contains a wide range of airports worldwide with highest movement and passenger numbers, relevant for technology evaluation.

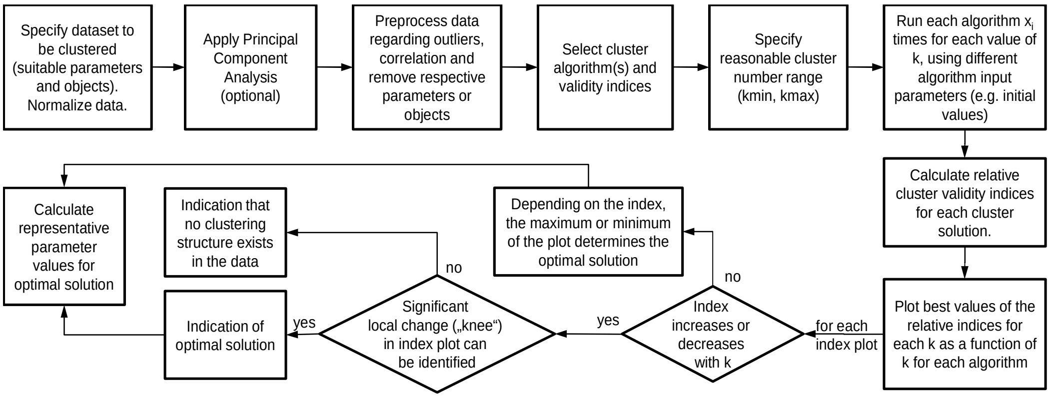
Particularly for the capacity-related assessment, the airport dataset had to be further reduced, since the 287 airports still contained a considerable amount of airports with very low movement numbers per hour, for which the peak detection algorithm resulted in errors. Comparing a visual error classification of peak detection with the maximum number of movements occurring at the respective airport, airports below a maximum of 16 movements per hour should be removed. Taking into account that lowest official numbers for slot facilitated airports in Germany are at 18 movements per hour, this limit was incorporated, resulting in a final airport dataset of 203 airports.

To determine the traffic parameters for the airports selected, OAG traffic data available for the year 2008 is used. Usually, the summer season shows higher movement numbers due to holiday travel. Hence, this season was considered, as critical peak situations and movement distribution features are reflected more clearly during summer season. Analyzing daily hourly movement distributions of airports during a whole week showed that there can be considerable variations, especially regarding the occurrence and characteristics of peak situations. Hence, seven consecutive days of scheduled movement data from OAG were taken into account. Airports with significant deviations during a week, e.g. Paris Orly or Las Palmas, can be considered as distinct airports in terms of varying movement characteristics. In order not to apply artificial weighting to airports that show weekly variations, each day is treated as a separate airport for the whole airport dataset (e.g. MUC1 to MUC7). Analyzing OAG data, it could be determined that the months of June, July and September 2008 showed highest worldwide movement numbers of that year. Since in previous studies the busiest day of the year for Munich Airport in June 2008 was used, the week containing this day was taken into account for the final analysis.

3. CLUSTER ANALYSIS

A systematic approach to find similar groups of objects in a dataset by use of cluster analysis was already introduced for the traffic peak analysis in Öttl et al. (2013). In the current paper, the cluster analysis process is further improved and extended, for instance by incorporating several cluster algorithms. The stepwise process of cluster analysis applied in this paper is presented in Figure 5. It starts with the selection of similarity parameters and data objects. Generally speaking, the smaller the number of similarity parameters, the smaller the number of objects required to get reasonable cluster results (referred to as "curse of dimensionality" (Theodoridis, 2009). A standardization of cluster data to a mean of zero and a variance of one is applied to avoid an artificial weighting of certain parameters due to their difference in magnitude. Moreover, this is essential for the subsequent optional step of Principal Component Analysis (PCA). PCA is a technique to transform data variables into a new set of variables – the principal components – which are linear combinations of the original variables and uncorrelated among themselves. The principal components are specified such that the data variance is maximized for the first component and the remaining variance is accounted for by the subsequent components. Hence, they are ordered by the magnitude of data variance they comprise. Considering only a subset of the principal components for further analysis can serve as a data reduction technique compared to taking into account all original variables, while still incorporating components of highest data variance. Due to the presented features, application of PCA before clustering can help to identify reasonable cluster solutions more clearly. For a detailed description of PCA refer to Sharma (1996).

Figure 5: Stepwise Cluster Analysis Approach (k denotes the Number of Clusters)



Notes: The process includes data preprocessing, application of cluster algorithms and an assessment to identify the optimal cluster solution (cluster validity process based on Halkidi et al. 2001).

In the pre-processing step, the input dataset is analyzed regarding the correlation between parameters and regarding outlier objects. In case a PCA is applied to the data, no correlations will occur. Outliers can distort the results and, thus, should be removed. Various methods for outlier detection exist in literature, of which the Local Outlier Factor (Breuning et al. 2000) was selected.

The type of cluster algorithm used largely depends on the data to be clustered without a universally applicable best cluster algorithm. Hence, it is recommended to take into account several applicable algorithms and compare the results (Sharma 1996). There is a large variety of cluster algorithms, some of which are applicable with certain restrictions only. An algorithm can, for instance, be intended for large datasets only. However, specification of dataset size differs. Since the number of airports addressed in this paper constitutes a small to medium size dataset compared to the specifications in Han et al. (2012) and Abu Abbas (2008), algorithms specifically mentioned to be applicable to this type of data were considered. Han et al. (2012) stated that partitioning methods, such as k-means, are effective for these dataset sizes. Abu Abbas (2008) concluded that hierarchical algorithms and self-organized maps are recommended for small datasets. Moreover, it was important that the algorithms are easily implementable and show a low demand in computation time. Hence, k-means and k-medoid (PAM) – two partitioning methods – and agglomerative hierarchical clustering were finally selected. For a description of the algorithms refer to literature (e.g. Gan et al. 2007, Han et al. 2012 or Theodoridis et al. 2009).

The behaviour of many cluster algorithms depends on features of the dataset analyzed as well as initial conditions and parameters required for the method (Halkidi et al. 2001). Therefore, several cluster approaches are necessary, followed by a so-called cluster validity assessment to identify a potential optimal cluster result. Moreover, many cluster algorithms require the number of clusters to be specified beforehand, which is usually not possible, since this number is also among the results. Thus, Halkidi et al. (2001) presented a process of cluster validity assessment incorporated in this paper and accounting for the remaining steps in Figure 5. It is proposed to repeat each algorithm for different cluster numbers k and different algorithm input parameters (mainly initial conditions). For each of the results, cluster validity indices can be calculated. Many indices have been defined and analyzed in literature (see also Halkidi et al. 2001 and Theodoridis et al. 2009). The indices taken into consideration for this approach are the Calinski-Harabasz (CH), Davies-Bouldin (DB), Dunn (DI) and I-Index (I), of which the first three are widely known. In a performance study by Maulik et al. (2002) the I-Index was described as the most reliable of the mentioned indices and hence has been included in the analysis process. Plotting the maximum (or minimum) of the respective index versus the number of clusters can help to identify an optimum. In case a clear global optimum cannot be identified, also local optima or "kinks" in the graphs can be an indication for an optimal cluster result. Of course, there is still a certain part of subjectivity in the interpretation of the quality of a clustering result and different indices can result in distinct potential optima. However, this approach offers a systematic way of addressing this issue.

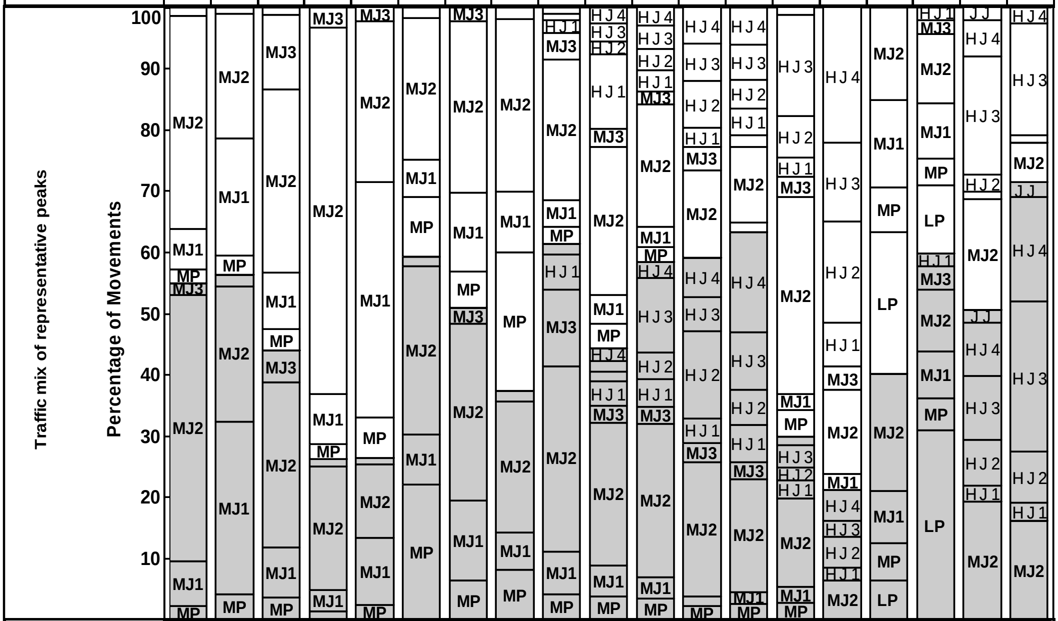
4. REPRESENTATIVE AIRPORT AND PEAK CATEGORIES FOR CAPACITY RELATED APPLICATION

The cluster analysis approach presented above was applied to the example application of airport capacity related technology evaluation. Since all of the similarity parameters mentioned in section 2.1 (peak related, airport traffic mix and movement distribution related) are of interest for a capacity-related airport categorization, it would be optimal to take all of them into consideration at once. Unfortunately, the more parameters are taken into consideration for clustering, the harder it is to determine distinct groups of similar characteristics. Hence, it was decided to apply the presented cluster approach separately to an airport dataset and a peak dataset and combine the results afterwards. Peak-related parameters are specified with reference to a peak situation only and do not depend directly on parameters of the daily airport traffic at the respective airport of occurrence. Therefore, this separation is reasonable. Nevertheless, peaks reflect some of the characteristics of the airport daily traffic and hence a later recombination is useful.

The peak cluster assessment resulted in an optimal solution of 19 representative traffic peak situations. Resulting parameter values are shown in Figure 6. Labels for aircraft weight classes are provided for values ≥ 2% for clarity. Traffic mix shares for departures and arrivals (shaded in gray) are provided separately. Peaks are presented in their order of cluster size, being the number of original peaks that formed the clusters. It can be observed that the results contain significant arrival and departure peaks and that the most representative peaks do not contain heavy aircraft traffic. The fact that strong variations in the arrival/departure ratio result is positive, since it reflects the actual range of ratios occurring in reality. As a main difference to the assessment in Öttl et al. (2013), the optimal number of clusters is slightly changed. This is mainly due to the additional shape parameters added and the extended airport data basis. However, comparing the features of the clusters clear similarities can be observed. The additional shape parameters are provided in the table in Figure 6. The resulting peak duration is between 2.5 and 3.1 h for most of the peaks, with the major exception of peak type 7. This cluster contains airports reaching capacity limits during certain periods (e.g. Frankfurt). It has to be mentioned that the peak duration is defined as the bottom peak duration and not as the duration at the top movement number of the peak. The fill factor can then provide additional information on the degree of pointedness of the traffic situation. A peak situation with high relative amplitude is preceded and/or followed by a situation of lower absolute movement numbers compared to peak situations with low relative amplitude. In general, peaks with lower relative amplitude offer fewer possibilities for recovering from delays or movement shifts after the peak situation and are thus most critical in terms of capacity considerations.

Figure 6: Resulting 19 Representative Traffic Peaks ordered by Cluster Size

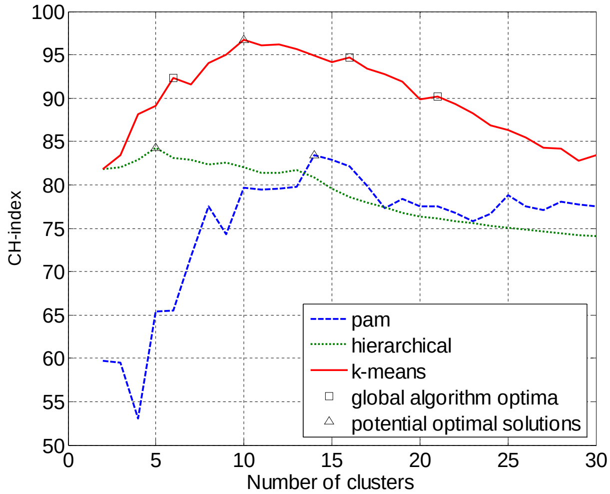
Cluster number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Num. peaks	2839	2002	897	818	808	792	780	772	669	409	326	202	183	165	85	83	74	17	15
Num. airports	142	96	86	109	68	60	137	63	70	47	39	21	26	21	7	6	4	2	1
Duration [h]	2.4	2.6	2.5	2.8	2.8	2.5	6.9	2.6	2.8	3.1	2.6	2.5	2.7	2.6	3.6	2.6	2.4	5.0	3.8
Fill factor [%]	54	54	55	54	53	54	51	53	54	53	53	55	56	55	55	50	52	55	48
Rel. amplitude [%]	41	49	43	59	61	49	58	51	49	46	44	41	42	55	54	54	55	48	45



Notes: The peak traffic mix is provided by the bar graphs (for specification of aircraft weight classes see Figure 11 in Appendix), divided into arrivals (gray) and departures (white). The three additional shape-related parameters are listed below the bar graphs.

Application of the cluster analysis process to the airport-related data resulted in a global optimum index value for the CH-index for each of the three algorithms applied (see Figure 7). Highest overall index values were reached for k-means, hence the index graph of this algorithm was further investigated. Apart from the global optimum at 10 clusters, several local optima could be identified. Comparing the deviation of cluster median results from the original airport dataset resulted in 16 clusters being the overall optimal solution. Analyzing original traffic parameter deviations of individual airports from cluster median values indicated that the median of the absolute deviations in percent lies below 10 for medium jet aircraft and below 1 for heavy type aircraft.

Figure 7: Highest CH-index Values for Three Different Cluster Algorithms Plotted over the Number of Clusters



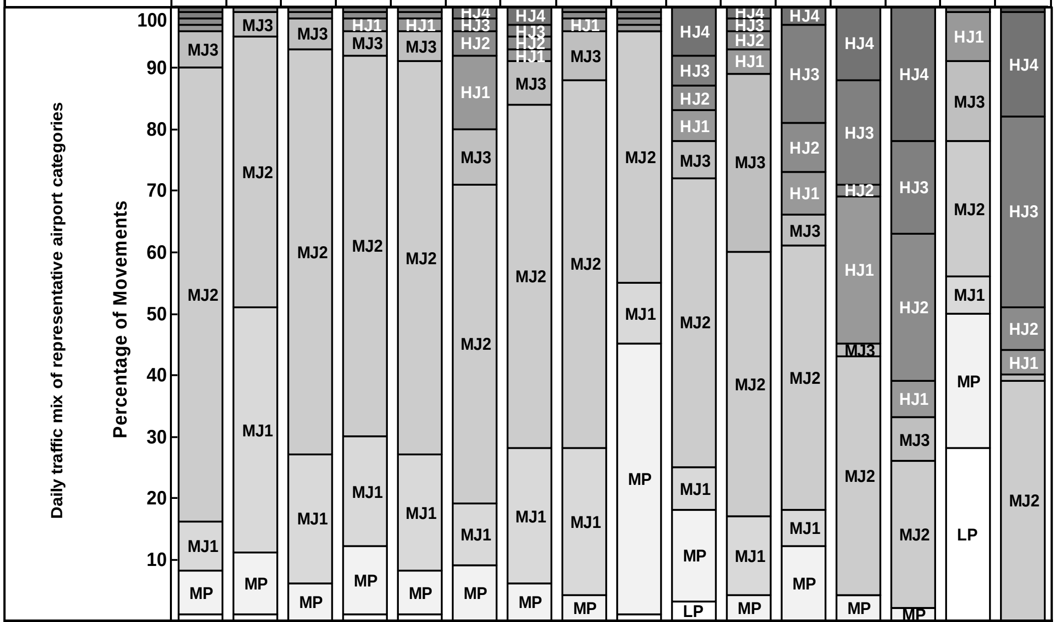
Notes: K-means shows highest values. Comparison and plausibility check of the global optimum (10 clusters) and local optima resulted in a final selection of 16 clusters.

The resulting representative airport categories for daily traffic mix and movement distribution related parameters are shown in Figure 8. The airport categories are ordered by the cluster size, which is specified by the number of airports considering seven days of the week.

It can be observed that airport categories of highest worldwide relevance are characterized by a high share of medium type aircraft. Category 1 contains primarily worldwide hub airports of different size, but also several origin and destination airports. Categories 2-5 contain a mix of different types of airports. Category 6 contains mainly hub airports, particularly in the Americas and Asia-Pacific region. Airport category 7 contains large hub airports that are characterized by a high traffic load throughout the whole day, such as Frankfurt or Chicago O'Hare. This is also reflected by the cluster result for the fill factor, which is highest for this category. Moreover, this category includes the highest share of worldwide large hub airports. The largest amount of smaller airports at touristic destinations as well as several origin and destination airports is contained in category 8, showing the lowest fill factor and a low relative load. In terms of night rest, category 10 contains several airports that allow considerable traffic during night hours (such as Dubai airport), resulting in the relative night rest of only 41%. Among the set of 16 categories there are also less representative ones in terms of cluster size (see right of Figure 8). Category 16, for instance, only contains seven days of the week of Singapore airport. However, this leads to a small share of JJ type aircraft in the traffic mix for this category. The largest share of light propeller aircraft has category 15, containing only a few different airports. Category 14 has the highest share of heavy aircraft traffic. It mainly contains four airports (for seven days a week) - ICN, TPE, HKG, AUH - which are large intercontinental hubs.

Figure 8: Resulting Representative Traffic-related Airport Categories Displayed in the Order of Cluster Size

Cluster number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Num. airports (7 days)	263	255	129	123	120	71	70	62	52	51	38	36	35	28	26	7



Total peaks	3	3	4	6	4	3	2	3	4	4	4	4	3	4	3	3
Arrival peaks	3	3	5	3	6	3	4	2	4	4	3	3	3	3	3	3
Departure peaks	3	3	5	3	2	3	3	2	4	2	3	3	2	2	2	2
Fill factor [%]	61	61	70	66	65	63	81	42	62	70	65	57	59	62	52	72
Relative load [%]	17	16	30	23	22	21	64	15	19	22	20	13	23	19	13	20
Rel. night rest [%]	88	87	80	92	90	89	76	101	94	41	86	99	99	80	100	46

Notes: 16 clusters were determined as the optimal solution for the combined cluster analysis of the daily traffic mix and movement distribution parameters. The bar graphs present the resulting daily traffic mix (a list of percentages is shown in Table 2 in the Appendix; for specification of aircraft weight classes see Figure 11 in Appendix). Movement distribution parameters are given in the table below the bar graphs.

The results for representative peaks and airports can now be combined. Therefore, first, the occurrence of a peak situation of an original airport in each of the representative peaks is counted for all airports analyzed. Then, peak occurrences are added for all airports in each representative airport category determined. Finally, the occurrence of representative peak types in each airport category can be provided in descending order of frequency. The highest three frequencies, hence, the most relevant peak situations for each airport category, are provided in Table 1.

Table 1: Most Relevant Peak Types in Representative Airport Categories

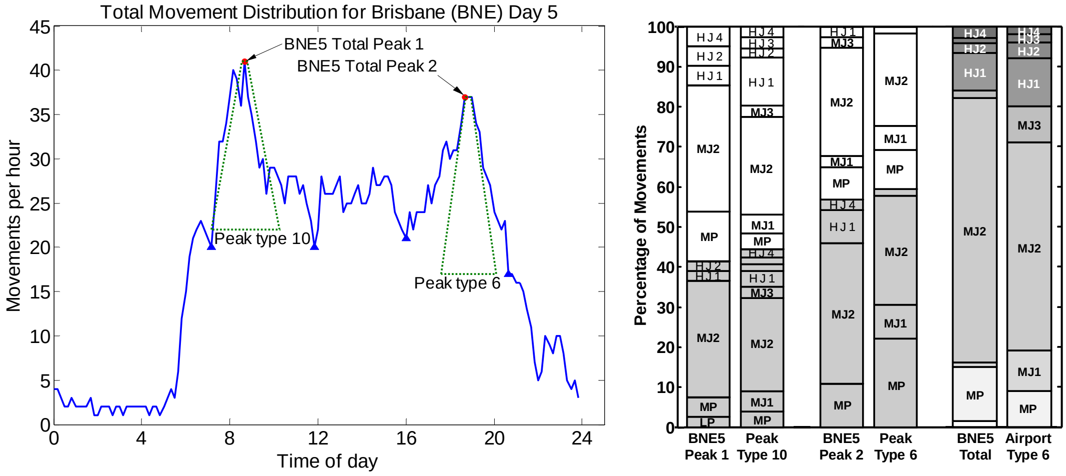
Representative Airport	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1st relevant peak	1	2	1	1	1	9	1	2	6	1	9	11	10	12	17	18
2nd relevant peak	4	5	2	6	2	10	2	5	8	13	3	14	11	13	16	19
3rd relevant peak	7	7	3	8	4	3	7	1	7	3	10	6	13	15	9	14

Notes: Only the three most relevant representative peak types (according to Figure 6) in representative airport categories of Figure 8 are shown, ordered by frequency of occurrence of peaks.

This list gives an indication of reasonable airport-peak combinations. However, it should be kept in mind that in Table 1 only the three peak types with highest frequency of occurrence for each category are listed and that, depending on the overall number of airports in a category, relevance of other peaks can still be significant. Especially for more representative categories containing many airports further peaks should be considered.

For a final demonstration of the quality of the representative categories of airports and peaks, a comparison is presented for one example airport (Brisbane BNE, day 5). Its daily movement distribution is shown in Figure 9 on the left, including two identified peaks. By comparing total absolute deviations of traffic mix percentages in the two peaks with all representative peaks of Figure 6, the closest peak type could be determined. A traffic mix comparison for both peaks is shown in Figure 9 on the right. It can be observed that arrival/departure ratios for both peaks are close to the original values. Representative values for duration, fill factor and relative amplitude were used to indicate the shape of both closest representative peaks (see dashed peaks in Figure 9). It can be observed that peak amplitudes are well met, while the representative peaks underestimate the original peak duration. Analyzing the total movement distribution, BNE airport on day 5 resulted in airport category 6 during the cluster process. Taking into account Table 1, peak types 9, 10 and 3 are most relevant for this type of airport, of which type 10 appears in the BNE example. As shown in Figure 9 on the right, the total airport traffic mix for airport type 6 is close to the original data for BNE. Movement distribution shape-related parameters for BNE are given in Figure 9 on left. Values are of similar order of magnitude compared to the representative airport type.

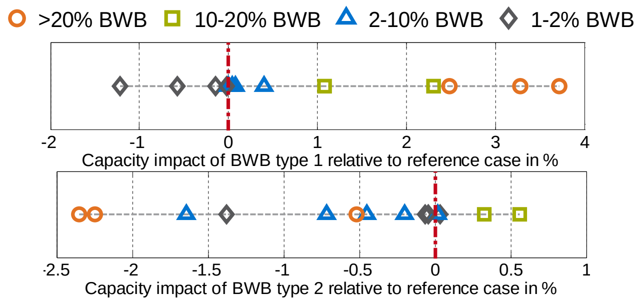
Figure 9: Airport Example Brisbane (BNE) compared to Representative Airport Category and Closest Representative Peak Types



Notes: The daily movement distribution and shape-related peak and airport features are shown on the left, the traffic mix structure is compared on the right.

The resulting representative airport and peak clusters can now be directly fed into runway capacity impact analysis. Each peak and airport cluster resembles a certain environment condition for which the capacity impact is determined. As a result, a range of impact values is determined, covering most relevant traffic situations worldwide. Figure 10 provides an exemplary result for the capacity impact range of two distinct blended-wing-body (BWB) aircraft evaluated with the 16 representative airport environments (for more detailed information on this example analysis refer to Öttl, 2013). The BWB aircraft substitute the aircraft weight classes HJ3+HJ4+JJ. Since not all airports contain these classes, only the ones where this aircraft type is present are shown. Capacity impact is described by the relative change in movements per hour possible at an airport when the aircraft type to be analyzed is present. The overall negative capacity impact of BWB type 2 can be observed compared to a rather positive impact of BWB type 1. This example demonstrates the importance of considering a variety of most relevant traffic conditions and not only a few local ones, as these environment conditions have a substantial influence on the results.

Figure 10: Exemplary Results for Capacity Impact Range of Two Blended-Wing-Body (BWB) Aircraft, Determined for the 16 Representative Airports



Notes: Based on Öttl (2013). Only representative airports as in Figure 8 are shown that contain this BWB aircraft type. The clear difference in impact can be observed.

5. CONCLUSIONS AND OUTLOOK

The main objective for this paper was to derive a systematic approach for specification of representative environment conditions of interest for technology impact evaluation on a global level. In particular, the airport traffic environment was considered, being of interest for runway capacity related evaluation studies. In general, impact evaluation is crucial for new technologies or concepts, as the planning and management of an efficient transport system requires detailed knowledge about the characteristics of this technology, including potential ranges of impact. The presented methodical approach based on cluster analysis ensures that the applicability of the respective technology is analyzed in a worldwide diversity of typical traffic situations.

Due to the variety of parameters of interest for different types of evaluations, it is not possible to derive one overall airport categorization that contains all relevant features of airport traffic. It is necessary to carefully specify the major traffic-related parameters of importance for the evaluation method and then find similarities in worldwide traffic situations to determine a representative set of airport categories. For the exemplary field of runway capacity evaluations a set of similarity parameters that describe the daily movement distribution were defined and their suitability investigated. Fill factor, relative load and relative night rest were selected as suitable to differentiate between distinct traffic features. Application of a systematic cluster-based assessment on traffic mix and movement distribution related parameters of 203 airports, analyzed for seven consecutive days, resulted in a set of 16 representative airport categories. This limited set of representative airports can serve as a standard input for capacity-related evaluations and ensure clarity and comparability on a technology level. By use of only a few representative types of airports, the worldwide diversity can be addressed and managed, without losing situations of importance. Additionally, 11936 traffic peak situations at airports were clustered according to their traffic structure and shape-related parameters, resulting in 19 representative categories. Each of the resulting representative airport categories could then be related to most relevant peak traffic situations.

Apart from the capacity example presented, this systematic approach to derive representative airport categories can also be applied to other fields. A further example for which traffic-related categories are needed is noise-related technology evaluation. Similar to the approach for capacity-related applications, similarity parameters of importance can be derived from the evaluation methods used. Considering the noise simulation software INM as an application example, the basic specification requirements include traffic on a daily basis, divided into day, evening and night time period, depending on the noise metric of interest (FAA, 2007). The share of movements for day, evening, and night time (according to EC, 2002), as well as the traffic mix structure for each period could be considered as potential similarity parameters in this context. Applicability of the presented approach is not only limited to traffic-related parameters. Similarities between any kind of entities or structures in air transport, such as airlines or air traffic control, can also be considered.

Taking only the current state of worldwide traffic into consideration to evaluate new technologies is a first step but not sufficient. Since new technologies are mainly introduced in future situations, a method has to be defined on how plausible future traffic situations can be determined. One possibility is to make use of scenario techniques to specify plausible future developments of environment conditions. The example presented in Öttl (2013) incorporates this type of approach.

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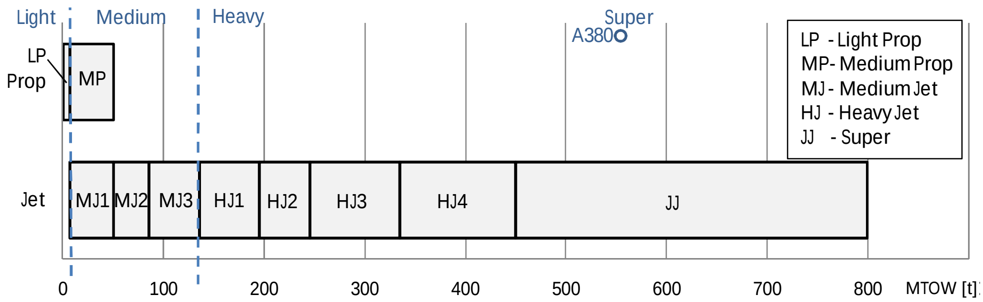
REFERENCES

- Airports Council International (2007). *ACI World Airport Traffic Report 2006*, ACI World Headquarters.
- Abu Abbas, O. (2008). Comparison Between Data Clustering Algorithms, The International Arab Journal of Information Technology 5(3): 320-325.
- Al-Zoubi, M. (2009). An Effective Clustering-Based Approach for Outlier Detection. *European Journal of Scientific Research* 28(2): 310-316.
- Ashford N., Stanton, H. P. M., Moore, C. A. (1991). *Airport Operations*, 1st edition, Pitman Publishing.
- Böck, P., Hornung, M. (2012). Airport capacity representation based on airside simulations, *ICAS Conference*, Brisbane.
- Böck, P., Schinwald, C., Phleps, P. (2011). Airport capacity impact of new aircraft concepts: how to manage airport diversity and individuality, *CEAS Aeronautical Journal* 2(1-4): 3-10.
- Breunig, M., Kriegel, H., Ng, R., Sander, J. (2000). LOF: Identifying Density-Based Local Outliers. *Proceedings of the 2000 ACM SIGMOD International Conference On Management of Data* 29(2): 93-104.
- EC (2002). directive 2002/49/EC of the European Parliament and of the council of 25 June 2002 relating to the assessment and management of environmental noise*, Official Journal of the European Communities*.
- FAA, ATAC, VNTSC (2007). *Integrated Noise Model (INM) Version 7.0 User's Guide*.
- Gan, G., Ma, C., Wu, J. (2007). *Data Clustering - Theory, Algorithms, and Applications*, ASA-SIAM, Philadelphia.
- Han, J., Kamber, M., Pei, J., (2012*). Data Mining – Concepts and Techniques*, 3rd edition, Morgan Kaufmann.
- Halkidi, M., Batistakis, Y. and Vazirgiannis, M. (2001). On clustering validation techniques, *Journal of Intelligent Information Systems* 17(2/3): 107-145.
- Maulik, U., Bandyopadhyay, S. (2002). Performance Evaluation of Some Clustering Algorithms and Validity Indices, IEEE Transactions on Pattern Analysis and Machine Intelligence 24(12): 1650-1654.

- OAG (2008). *OAG – Official Airline Guide*. Flight data from 13th of June 2008.
- Öttl, G., Böck, P. (2011). An approach to airport categorization – category definition and quantification for air traffic related simulation purposes, *Journal of Aerospace Operations* 1: 1-16.
- Öttl, G., Böck, P., Werpup, N. and Schwarze, M. (2013). Derivation of Representative Air Traffic Peaks as a Standard Input for Airport Related Simulation, *Journal of Air Transport Management* 28: 31-39.
- Öttl, G. (2013). Representative traffic situations for air transport technology evaluation, *World Conference on Transport Research (WCTR),* Rio de Janeiro.
- Sharma, S. (1996). *Applied Multivariate Techniques*, John Wiley & Sons.
- Theodoridis, S. and Koutroumbas, K. (2009). *Pattern Recognition*, 4th edition, Academic Press.

APPENDIX

Figure 11: Aircraft Weight Classes for Traffic Mix Parameterization



Notes: Derived from Öttl et al. (2013).

Table 2: Data Table for Traffic Mix Distributions of Representative Airport Categories in Figure 8

Represent. airport		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Daily traffic mix in % movements	LP	1	1	0	1	1	0	0	0	1	3	0	0	0	0	28	0
	MP	7	10	6	11	7	9	6	4	44	15	4	12	4	2	22	0
	MJ1	8	40	21	18	19	10	22	24	10	7	13	6	0	0	6	0
	MJ2	74	44	66	62	64	52	56	60	41	47	43	43	39	24	22	39
	MJ3	6	4	5	4	5	9	7	8	0	6	29	5	2	7	13	1
	HJ1	1	1	1	2	2	12	2	2	1	5	4	7	24	6	8	4
	HJ2	1	0	1	1	1	4	2	1	1	4	3	8	2	24	0	7
	HJ3	1	0	0	1	1	2	2	1	1	5	2	16	17	15	1	31
	HJ4	1	0	0	0	0	2	3	0	1	8	2	3	12	22	0	17
	JJ	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

FROM CARPET SELLERS TO CARGO STARS: ANALYZING STRATEGIES OF AIR CARGO CARRIERS

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ABSTRACT

While some research has been done on passenger airlines strategy, the strategies of air cargo carriers have hardly been researched. This paper analyses and compares the strategies of air cargo carriers. Therefore, a typology of management strategies for both combination and full cargo airlines has been developed, in which the various strategy choices within the strategic framework of the respective air cargo carriers are further elaborated. The typology has been developed through a K-means cluster analysis on a data set of 47 air cargo carriers. The use of a cluster analysis to group the strategy models of a number of air cargo carriers is a novel feature of this research. The results of this research generate a typology of seven representative clusters of air cargo carriers' strategy models, each with their own characterizing features. Striking differences and similarities are highlighted. Our findings suggest the clear existence of different strategy models and the differing degree of focus on air cargo strategy development and deployment among the air cargo carriers' population.

Keywords: management strategy, air cargo carriers, cluster analysis, typology

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1. INTRODUCTION

This paper deals with the business level strategies of air cargo carriers. It focuses on the key indicators constituting the building blocks of a global strategic framework for air cargo carriers, encompassing both belly-hold and full freighter cargo operators (or a combination of these). The integrators have been excluded of the scope of this paper.

Air cargo is a major mode by which the globalized world moves its valuable consumption goods and manufacturing components. Through its role in the supply chain, it facilitates worldwide economies and their international trade. It has also proven to be an effective way of connecting mainly Asian labour with some European and North American consumption markets. With time-definite international transactions materialized in an increasingly globalized and complex supply chain, with enhanced production flexibility and with speed characterizing much of the new economy, air cargo will undoubtedly play an increasingly vital role in the global economy. The last decades, global export growth has consistently outpaced production growth, and global air freight growth has outpaced GDP growth, despite recessions and other set-backs to air transport2.

The global air cargo industry represented in 2008 about 87 billion $ in direct revenue (Air Cargo Management Group, 2009) and substantially more in related supply chain services. Therefore, this industry can nowadays be considered to be a mature industry, where strategy is drafted far beyond the basic entrepreneurial framework in which an emerging industry tends to operate.

Table 1, enumerating the Top 25 of FTK's performed in 2010 (IATA, 2011) by airlines, shows that 22 out of the 25 positions are taken by combination (passenger and cargo) carriers. Positions 1 and 2 are occupied by integrators (Fed Ex and UPS). The only full cargo airline in this Top 25 taken by full cargo airlines is Cargolux on position 10. Noteworthy is that 61.28% of the world traffic is transported by the 23 regular combination carriers, while the Top 25 air cargo airlines represent a 76.09% share of the world's total freight traffic. The merger between Delta Airlines and Northwest, and Continental and United will further consolidate this picture. Freighters are extensively used by these airlines, as 53.24% of the top 25 air cargo airlines' cargo loads are transported by a freighter aircraft. About 14.8 percentage points of the

[2] The outbreaks of the Asian and Russian currency crisis, SARS, the events following the 9/11 terrorist attack, the recent monetary crisis and resulting worldwide recession

world's total FTK's have been transported by the two integrators FedEx and UPS, and only about 2.8 percentage points by the full freighter company Cargolux.

Table 1: Leading 25 Air Cargo Carriers – Total FTK (2010)

Rank	Airline	FTK (million FTK)	% of world FTK	% tons by freighter	Rank	Airline	FTK (million FTK)	% of world FTK	% tons by freighter
1	Federal Express	15.741	8,99%	100%	14	KLM	3.698	2,11%	0%
2	UPS Airlines	10.194	5,82%	100%	15	Asiana Airlines	3.400	1,94%	68%
3	Cathay Pacific	9.587	5,47%	56%	16	China Eastern	3.245	1,85%	44%
4	Korean Air	9.542	5,45%	70%	17	Delta Airlines	3.152	1,80%	0%
5	Emirates	7.912	4,52%	20%	18	China Southern	3.083	1,76%	14%
6	Lufthansa	7.427	4,24%	47%	19	Qatar Airways	3.040	1,74%	29%
7	Singapore Airlines	7.000	4,00%	35%	20	LAN Airlines	2.956	1,69%	62%
8	China Airlines	6.410	3,66%	86%	21	Thai Airways	2.894	1,65%	5%
9	EVA Air	5.166	2,95%	66%	22	Japan Airlines	2.849	1,63%	23%
10	Cargolux	4.901	2,80%	100%	23	Qantas Airlines	2.589	1,48%	14%
11	Air France	4.738	2,70%	27%	24	American Airl.	2.552	1,46%	0%
12	British Airways	4.498	2,57%	20%	25	United Airlines	2.502	1,43%	0%
13	Air China	4.223	2,41%	34%					
					TOP 25 Scheduled		70.972	76,09%	53.24%
Source : Own calculations with IATA WATS data -2011					Total Scheduled		175.170	100	50.88%

In addition, this introduction puts forward some strategic considerations on the air freight value proposition which is the justification for using air freight and the business model of air cargo carriers. A good understanding of this framework is a prerequisite to understand the context and framework in which air cargo carriers operate, and to be able to analyse the key drivers behind strategy development of air cargo operators.

When drafting a business level strategy, the value proposition of the air freight model needs to be taken into account at all times. Compared to surface modes air freight offers a faster speed and a greater reliability. A shift in modes will take place if the value proposition changes due to a shift in price or perceived level of service. While recent inventory strategies tend to favour air freight, a shift from air to surface can for instance occur when high air cargo fuel charges lead to a shift to trucking and ocean services for less time critical freight. Noteworthy in this respect is the consensus among air cargo executives that, apart from the mainly IATA driven e-freight developments and the mainly manufacturer driven introduction of new technology aircraft, the air cargo product lacks recent service and productivity innovations (Air Cargo Management Group, 2011).

A direct result of this air freight value proposition, is the fact that the customer's rationale for using air freight needs to be clarified and defined in order to build an overall strategy which sustains this rationale. The main reason why a customer selects air freight is its speed and reliability, allowing him to respond rapidly to shifts in demand and this on a global scale and on a 24 hours basis. For the customer, this generates cost savings as far as the inventory levels and stock-out risks are concerned. Generally goods with a high value per kg and higher value perishable goods (flowers, fish) move by air. Less than 2% of total international freight tonnage, representing 36% of total value of trade value, travels as air freight (figures of 2011) (Des Vertannes, 2012).

A distinct feature of the air cargo industry is that its business model differs significantly from the air passenger business model. However, these models are often mixed in one single airline entity as about half of the world's air cargo is moved in the belly-hold of passenger aircraft. Therefore, the network planning and operations for half the capacity are dictated by demands of the passenger market (Kadar and Larew, 2004, p. 3-9).

In the second section of this paper the indicators are defined and set for the most significant key and supporting components within the strategic framework of air cargo carriers. The third section shows the results of a K-means Cluster Analysis on the data which have been collected for the above mentioned components for a representative sample of 47 air cargo carriers. The fourth section presents a typology of seven representative clusters of air cargo operators' strategy models as a direct output of this Cluster Analysis. The final section elaborates further on the range of strategy models. Striking differences and similarities are highlighted. Interesting is to observe in which cluster and on what basis each of the individual airlines from the sample is situated.

2. KEY INDICATORS OF A BUSINESS LEVEL STRATEGY

Figure 1 provides an overview of the influencing components for each part of the management strategy (Dewulf, Vanelslander and Van de voorde, 2010). Management choices and decisions on the set of influencing components define the features of the respective product, market and network strategy. The following set of influencing components determines the product strategy of an air cargo operator: product differentiation, yield management, route network, customer relation management, environment and alliances. The impact on the business level strategy of choices on each of these variables is explained below.

Figure 1: Influencing Components in the Development of a Management Strategy

Product differentiation is a very important component in this area. Air cargo was traditionally seen as a by-product of passenger transport. Pricing was based on marginal cost, and there was no separate cargo division taking responsibility for sales and operations. This has changed considerably in the course of the last decade as a number of operators consider air cargo increasingly as a revenue enhancing product, often differentiated through innovative marketing. Therefore, marketing concepts for time-definite products, high value goods, cool chain products and livestock often differentiate the basic cargo product. Closely related to product differentiation is yield management. Product differentiation is used as a means to increase revenue per ATK. A close monitoring of available and booked capacity on each route on each direction on a specific period can increase revenues per ATK significantly. Route network development is also closely related to yield management. Adding a route on the network does not only increase revenues on this particular route, but also creates additional connections for other routes, and therefore increases the total revenue and yield potential of the entire network. A well performing Customer Relation Management (CRM) creates short term customer satisfaction and a long term commitment from the customer. A strong CRM, where personal attention to the customer is provided, and the build-up of an extensive sales force are costly structures to set up and maintain. However, a long term relationship with the customer, often contractually agreed for a longer term, is beneficial for both yield and capacity management planning. Therefore, the larger air cargo operators such as Lufthansa Cargo, Emirates Sky Cargo, AF-KLM Cargo and BA Cargo have separate and dedicated sales teams to market their cargo products and fill up capacity. Some customers are attracted to creating an environmentally friendly image and business attitude and require an environmentally friendly cargo product. CO_2 off-set programs and environmentally friendly aircraft are used to differentiate the cargo product from competitors. As it is the case with the CRM programs discussed above, the larger cargo operators tend to be more involved with this kind of product differentiation.

Another set of influencing components determines the development of a market strategy for an air cargo operator: capacity management, competitive market behaviour, hub choice, route network, relationship with integrators, the usage of E-portals, and alliances. A crucial part in the market strategy is a performing and outstanding capacity management. Adjusting capacity in favour of the demand on routes enhances revenues and yields. Additional capacity at the right price can also attract demand. However, air cargo operators can do little in the aggregate sense to influence demand for their services (Air Cargo Management Group, 2006, p. 21), mainly because the demand for air cargo transportation is a derived demand from external factors. Management's skill to calibrate the mix between short term spot capacity availability and long term capacity contracts with customers is another crucial factor. Therefore, capacity and yield management go hand in hand and are both crucial decision parameters on which a strategy is to be developed. A tool to protect and defend yield and capacity management on a certain route or network is the competitive behaviour versus direct competitors. This can be done by adapting the price, enlarging the capacity on a route or enhancing the product for the customer. Predatory pricing, although restricting competition and illegal in a number of countries, can be used to undermine profitability on routes where and when a new entrant starts selling capacity. Route network development and the location choice of hubs are other major elements to build a coherent market strategy. The relationship with integrators has always been a difficult balance between competing with them by offering an up-market door-to-door product (through vertical alliances), similar to the product offered by integrators, and caring for them as important customers. The usage of E-portals creates transparency for the customers, and facilitates booking capacity. Moreover, it provides a fast and transparent way to sell excess spot capacity for the operator. Therefore, the connection to an E-portal, and the adequate usage of it for capacity management should be taken into account while determining a market strategy.

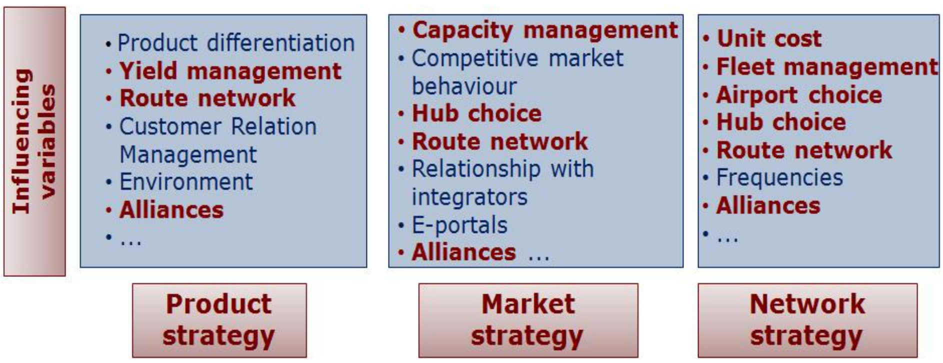
A final set of influencing components that determine the development of a network strategy are: unit cost structure, fleet management, airport choice, hub choice, route network, frequencies and alliances. The set-up and build-up of a network, with its determining variables, is a major driver for the cost structure of an air cargo carrier.

Fleet choice, and especially the introduction of full freighter operations, has a significant impact on capacity and unit cost for air cargo operations. Important decisions for the management strategy development are where to locate a hub, which markets to serve at which frequency, and which airports to operate within these markets.

Alliances are a common theme in the strategy development and are omnipresent in the product, market and network strategy. A number of theoretical drivers for cargo alliances can be identified, similar to the drivers for passenger alliances. However, up to now success with cargo alliance formation has been very limited. Most initiatives such as the WOW cargo alliance and Jade Cargo International, a joint venture between Lufthansa and Shenzhen airlines, have failed due to mistrust among and sub-optimization of capacities and revenues from partners. The only alliance which works reasonably well within the general 'Big 3' alliance frameworks (One World, Star Alliance and Sky Team) is the Skyteam Cargo alliance. Still, alliances created for a specific purpose and cemented in a joint venture tend to work better. Typical examples are Aerologic, a joint venture created between Lufthansa and DHL to perform long haul cargo air transport mainly on behalf of DHL, and Shanghai Airlines Cargo International, a joint venture between EVA Airways and Shanghai Airlines, to serve the large and fast growing Chinese air cargo market.

A number of indicators will be selected for the most significant components in the above mentioned business level strategy framework. The red-marked influencing components can be measured by an appropriate numeric indicator as indicated in figure 2 below.

Figure 2: Key Components to be measured by an Appropriate Numeric Indicator



Tables 2 and 3 below propose for each marked component a key indicator. The numeric indicators set out in the table are self-explanatory. Data are available, however scattered, through both IATA and ICAO publications, and annual reports of the respective airlines.

Table 2: Numeric Indicators for Influencing Components

Key variable	Key indicator	Output
Operating revenue	Operating revenue	USD
Operating cost	Operating cost	USD
Operating profit/loss	Operating profit/loss	USD
ATK	Available Ton Kilometers for combi and freighter a/c	Number
RTK	Revenue Ton Kilometers for combi and freighter a/c	Number
Kilometers Flown	Kilometers Flown for combi and freighter a/c	Km
Hours Flown	Hours Flown for combi and freighter a/c	Hrs
Tons Carried	Tons Carried for combi and freighter a/c	Tons
Aircraft Departures	Aircraft Departures for combi and freighter a/c	Number
Member of an Alliance	Member of Sky Team, Star Alliance, One World, Preparatory stage or none	SKY/STAR/ONE/ PREP/NONE
Hub performance	Metric tons at main hub Ranking of hub in the world	Tons Number
Passenger Aircraft	Number of passenger aircraft in service	Number
Freighter Aircraft	Number of freighter aircraft in service	Number
Employees	Number of employees in service (FTE's)	Number

Table 3: Numeric Key Performance Indicators for Influencing Components

Key variable	K(P)I	Output
Operating revenue	Operating revenue/ATK	Number
Operating cost	Operating cost/ATK	Number
Operating profit	Operating profit/ATK	Number
Productivity	ATK/employee FTK/employee	Number Number
Yield management	Operating revenue/RTK and /ATK	USD
Capacity management	Weight load factor for PAX and freighter a/c	%
Route network	Avg. length transport (FTK/Tons carried) for pax and freighter a/c	km
Fleet management	% of tonnage transported by freighter a/c	%
Route network	Average stage length (Km flown/number of departures)	km

As most key components within a strategic framework are not 'pure' and might be influenced by a number of other sub-variables, the choice of the proxy variable and its key (performance) indicator can be debated. But since the meaning of the key component and the respective output are rather straightforward, the proposed choice of a key (performance) indicator is at least very approximate to rank its values and distinguish output among air cargo operators.

3. RESEARCH METHODOLOGY

To build a sound typology of air cargo carriers, a substantial data set is mandatory. Given the above mentioned heavily consolidated landscape of air cargo carriers, the top 25 international air cargo carriers of 2010 (Table 1) are to be included in the data set (Table 4). However, the scope of this research excludes integrators such as UPS and Fed Ex. Due to inconsistencies in the air cargo data for United Airlines, following the merger with Continental airlines, United Airlines has also been excluded from the data set. In addition, the data set is enlarged to include an additional 25 air cargo carriers, randomly chosen from each continent from the TOP 100 air cargo carriers, based on FTK.

Table 4: Representative Sample of 47 Airlines

Airline	IATA code	Airline	IATA code
Aeroflot	SU	EVA Airways	BR
Air Canada	AC	Garuda Indonesia	GA
Air China	CA	Gol Airlines	GO
Air France	AF	Gulf Air	GF
All Nippon Airlines	NH	Iberia	IB
American Airlines	AA	Japan Airlines	JL
Asiana Airlines	OZ	Jet Airways	9W
Atlas Air	5Y	KLM	KL
Avianca	AV	Korean Air	KE
bmi	BD	LAN Airlines	LA
British Airways	BA	Lufthansa	LH
Brussels Airlines	SN	Malaysia Airlines	MH
CAL Cargo Airlines	5C	Nippon Cargo Airlines	KZ
Cargolux	CV	Philippine Airlines	PR
Cathay Pacific Airways	CX	Qantas Airways	QF
China Airlines	CI	SAS	SK
China Eastern Airlines	MU	Saudi Arabian Airlines	SV
China Southern Airlines	CZ	Singapore Airlines	SQ
Continental Airlines	CO	South African Airways	SA
Delta Airlines	DL	Swiss	LX
El Al Israel Airlines	LY	Thai Airways	TG
Emirates	EK	Turkish Airlines	TK
Ethiopian Airlines	ET	Volga Dnepr Airlines	VI
Etihad Airways	EY		

Data have been collected for this representative sample of 47 international cargo airlines from the IATA World Air Traffic Report 2010 (IATA, 2011), World Airline Report 2010 (Air Transport World, 2011), annual reports and data supplied by the respective airlines. This sample represents 130,841 million scheduled FTK's, or 74.69% of the 175,170 millions of scheduled FTK performed worldwide. Data of 2010 are considered to be more stable than the 2008 (Q4) and 2009 (full year) data which are heavily impacted by the recent crisis. 2011 data, however not fully available at this very moment, show again an inconsistent pattern on a month-by-month basis.

In order to cluster the airlines into a number of respective groups of airlines, a K-means Cluster Analysis (with iterations) has been performed. PASW Statistics 18 (SPSS) has been used for this purpose. The Cluster Analysis has been executed with 5, 6 and 7 clusters. The initial Cluster Analysis with 5 clusters resulted in a generally logical airline distribution among the different clusters (table 5). There were no missing cases in the clusters; all 47 airlines were positioned in a cluster.

Table 5: Result of a Cluster Analysis with Five Clusters

Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5
Air France	Avianca	American Airlines	Air Canada	Jet Airways
British Airways	bmi	Delta Airlines	Air China	China Airlines
Continental Airlines	EVA Airways		Cathay Pacific	Gol
China Southern Airlines	Ethiopian Airlines		JAL	Iberia
Emirates	Etihad Airways		Korean Air	LAN
Lufthansa	Gulfair		KLM	Swiss
Qantas	El Al Israel Airlines		China Eastern	Malaysia Airlines
	Philippine Airlines		ANA	Asiana
	South African Airways		Singapore Airlines	Qatar Airways
	Brussels Airlines		Thai Airways	SAS
				Saudi
	CAL Cargo Airlines			Turkish Airlines
	Atlas Air			
	Nippon Cargo Airlines			Cargolux
	Polar Air Cargo			
	Volga Dnepr Airlines			

Cluster 1 consists of large prime operators, generating both premium passenger traffic and cargo flows. Cluster 2 groups the smaller airlines, operating more like an entrepreneur. The two very large US airlines are grouped in Cluster 3. Cluster 4 gives a relatively diverse image, with both large Asian and large airlines such as Air Canada and KLM present in this cluster. Additional Cluster Analysis (see further below) with more clusters will demonstrate that this group will be split. Cluster 5 is more consistent with member airlines operating from a large regional hub and with both a strong regional and long haul network. Only Cargolux looks like the odd one out in the group, and compared to the other full cargo carriers in Cluster 2. Reasons for this will be further explained below.

A K-means Cluster Analysis with 6 clusters, using the same data set, generates very stable and similar results in table 6. The additional cluster 6 divides the 'problematic' cluster 4 further into two more logical parts. Cluster 6 consists now of strong Asian passenger and cargo operators Air China, JAL, China Eastern airlines and ANA, originally located in cluster 4. EVA airways migrated from cluster 2 to cluster 5 which is more logical group to be part of. This airline is a strong player operating from Taiwan and operates both a good regional feeder network and long haul flights for passengers and cargo.

Table 6: Results of a Cluster Analysis with 6 Clusters

Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5	Cluster 6
Air France	Avianca	American Airlines	Air Canada	Jet Airways	Air China
British Airways	bmi	Delta Airlines	Cathay Pacific	EVA Airways	JAL
Continental Airlines	Ethiopian Airlines		Korean Air	China Airlines	China Eastern
China Southern Airlines	Etihad Airways		KLM	Gol	ANA
Emirates	Gulfair		Qatar Airways	Iberia	
Lufthansa	El Al Israel Airlines		Singapore Airlines	LAN	
Qantas	Philippine Airlines		Thai Airways	Swiss	
	Brussels Airlines			Malaysia Airlines	
				Asiana	
	CAL Cargo Airlines			South African Airways	
	Atlas Air			SAS	
	Nippon Cargo Airlines			Saudi	
	Polar Air Cargo			Turkish Airlines	
	Volga Dnepr Airlines				
				Cargolux	

Table 7 shows the results of a K-means Cluster Analysis with 7 clusters, using the same data set. This calculation generates no surprising results. The clusters remain very stable, while the new cluster 7 is formed by a migration of three airlines from cluster 4 and two from cluster 5. The new cluster 7 is a cluster with key indicators and key performance indicators situating between cluster 4 and 5. The migration from Korean Air, Thai Airways and Turkish Airline is due to less performing indicators compared to the former group member of cluster 4. On the contrary, the migration from cluster 5 to the new cluster 7 is due to generally better performing indicators than its former group members of cluster 5. This is not considered to be an enhancement of the typology model, as a homogenous group of Asian airlines with similar management strategy is split due to operational performance differences in the output.

Table 7: Results of a Cluster Analysis with 7 Clusters

Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5	Cluster 6	Cluster 7
Air France	Avianca	Air China	Air Canada	Jet Airways	American Airlines	Iberia
British Airways	bmi	JAL	Cathay Pacific	China Airlines	Delta Airlines	Korean Air
Continental Airlines	Ethiopian Airlines	China Eastern	KLM	Gol		Qatar Airways
China Southern Airlines	Etihad Airways	ANA	Singapore Airlines	EVA Airways		Thai Airways
Emirates	Gulfair			LAN		Turkish Airlines
Lufthansa	El Al Israel Airlines			Swiss		
Qantas	Philippine Airlines			Malaysia Airlines		
	Brussels Airlines			Asiana		
				South African Airways		
	CAL Cargo Airlines			SAS		
	Atlas Air			Saudi		
	Nippon Cargo Airlines					
	Polar Air Cargo					
	Volga Dnepr Airlines			Cargolux		

A comprehensive study of the data set reveals that the airlines 'on the move' in the Cluster Analysis with 6 and 7 clusters have a different charter output pattern. While data of the aircraft chartered for the execution of scheduled flights are counted as scheduled flights, the charter flights executed for third parties or other airlines are included in the operational data. This in fact distorts the operational parameters and resulting key performance indicators. Therefore, in order to fine tune the group of clusters, the same Cluster Analysis with 7 clusters is repeated but excluding the data related to charter flights. Table 8 below shows the results of the above mentioned exercise.

Table 8: Results of a Cluster Analysis with 7 clusters
(excluding data related to charter flights)

Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5	Cluster 6	Cluster 7
British Airways	Avianca	Iberia	Jet Airways	Air Canada	American Airlines	Air France
Continental Airlines	bmi	Korean Air	China Airlines	Cathay Pacific	Delta Airlines	Emirates
China Southern Airlines	Ethiopian Airlines	Qatar Airways	Gol	KLM		Lufthansa
Qantas	Etihad Airways	Thai Airways	EVA Airways	Singapore Airlines		
	Gulfair	Turkish Airlines	LAN	Air China		
	El Al Israel Airlines	ANA	Swiss	JAL		
	Philippine Airlines		Malaysia Airlines	China Eastern		
	Brussels Airlines		Asiana			
			South African Airways	Formed a separate cluster before		
	CAL Cargo Airlines		SAS			
	Atlas Air		Saudi			
	Nippon Cargo Airlines					
	Polar Air Cargo					
	Volga Dnepr Airlines		Cargolux			

A new cluster group has now been formed in cluster 7, with three airlines -Air France, Emirates and Lufthansa- originating from cluster 1. This is mainly due to the relative higher importance of cargo versus passenger traffic in the output parameters. The original cluster 7 is divided over two clusters. ANA joins cluster 3, and Air China, JAL and China Eastern Airlines join cluster 5. The latter are regrouped in cluster 5 mainly due to its higher yield and better operational output parameters. The proposed clusters will be used as a template for building a typology of air cargo carriers' strategies in the next chapter.

Table 9: Final Cluster Centres of a Cluster Analysis with 7 clusters

Final Cluster Centers

	Cluster						
	1	2	3	4	5	6	7
OPREVENUE	$22,553,287	$11,100,218	$1,534,167	$12,951,144	$3,991,004	$8,912,586	$26,962,500
OPCOST	$21,483,229	$10,510,341	$1,292,607	$11,855,880	$3,636,116	$8,338,975	$25,700,000
OPPROFITLOSS	$1,070,058	$589,877	$36,301	$1,102,407	$233,228	$512,175	$1,262,500
OPPROFITATK	0.037100000	0.030350000	0.001938462	0.067100000	0.026145455	0.036483333	0.029450000
OPPROFITRTK	0.141633333	0.249075000	-0.223730769	0.289185714	0.039781818	0.179700000	0.411950000
OPREVENUERTK	1.149970787	0.791455378	1.076589920	1.164826988	0.885321132	1.147577299	1.100594650
OPREVENUEATK	0.853752937	0.579354366	0.638285654	0.815068547	0.598585746	0.689848996	0.676487682
OPCOSTATK	0.816675848	0.548993231	0.488826178	0.748475771	0.574347421	0.649065601	0.647081474
OPCOSTRTK	1.099214279	0.748831778	0.840972302	1.068074428	0.820001810	1.082458141	1.053170281
KKMFLOWNSCH	720425	718307	71904	461014	191231	323087	1488909
ACDEPSCH	424357	400983	62638	233325	127815	174846	760844
HRFLOWNSCH	1115897	1094974	126102	693239	298471	508636	2283925
PAXSCH	44856814	48136770	4808634	30864157	15124854	24034807	98643890
FRTONSCH	1165468	579369	121964	936070	500988	765502	476764
KRPKSCH	132834964	111038028	7933606	78176991	28690568	53630997	234435293
KASKSCH	165710427	138053570	10594879	97717588	37947333	71885490	284069216
PAXLFSCH	,80	,80	,74	,80	,76	,75	,83
KPTKSCH	12671171	11008657	783438	7213989	2616847	4836016	21302503
KFTKSCH	6693061	2880958	834179	4584615	2518273	3344722	2852519
KMTKSCH	195714	149448	7397	148572	26731	75203	182560
TOTALKTKSCH	19559946	14039063	1423341	11947176	4937098	8255941	24337581
KATKSCH	26783385	19225357	2205484	16663143	6976703	12928283	39465242
WEIGHTLFSCH	,73	,74	,65	,71	,70	,64	,62
KKMFLOWNFREIGHTER	36644	14787	11132	33519	41529	24503	0
ACDEPFREIGHTER	8119	3100	2422	7902	9606	8153	0
HRFLOWNFREIGHTER	48930	19750	13857	43948	55063	51840	0
FRTONSFREIGHTER	341855	111502	130180	469541	511134	313582	0
KFTKFREIGHTER	2373207	1044672	853671	2521027	2909075	1629043	0
KMAILTKFREIGHTER	19732	1704	805	11791	9597	5765	0
TOTALKTKFREIGHTER	2392938	1045808	854387	2532819	2914560	1634807	0
KATKFREIGHTER	3361282	1516830	1181709	3393903	3916216	2059997	0
WEIGHTLFFREIGHTER	,70	,68	,63	,74	,70	,75	,00
PAXAC	310	291	29	183	82	124	670
FREIGHTERS	9	2	6	7	8	8	0
PROCUSEFREIGHTER	31,33	12,00	48,08	27,43	36,58	26,38	,00
EMPLOYEES	67675	30864	3706	21752	11503	17693	72496
ATKPEREMPLOYEE	550	816	1604	902	1088	795	545
FTKPEREMPLOYEE	136	126	909	250	533	199	40
METRICTONSHUB2010	2314890	785685	989386	2137679	815722	1304272	654857
RANKHUB2010	7	71	60	14	53	25	31
FTKFTCPAXAC	5845	5113	2069	4297	3736	4200	5981
FTKFTCFREIGHTER	6928	8170	3488	4282	2951	3949	0
AVGSTGLGTHPAXAC	2311	1956	954	2515	1503	2125	1968
AVGSTGLGTHFREIGHTER	4574	4199	2916	3602	4302	2082	0
TOTALMKTSHR	3,8333	1,6475	,6946	2,6343	1,4767	1,9117	1,6300

Table 9 shows the calculated Final Cluster Centres for the K-means Cluster Analysis (PASW 18, SPSS with iterations) with 2010 data, excluding the operational data for charter operations, from the same sample of 47 airlines. These data will be used to identify and explain the respective clusters' characteristics and associated management strategies of the group members of the respective clusters.

4. TYPOLOGY OF AIR CARGO OPERATORS

Dewulf, Meersman and Van de Voorde (2011a) distinguished a typology of five air cargo strategies, based on empirical deduction and clustering of data for a number of indicators and key performance indicators for a sample of 50 international cargo airlines. Similarities and differences in the values of each of the indicators compared to the average of indicators of the total population on the data set have demonstrated that the sample could empirically be divided in a typology of five groups, each with their characterizing features. Based on this research and the results of the Cluster Analysis in Tables 8 and 9, a typology of business level strategies of 7 groups of air cargo carriers can be built.

Table 10 gives a typology of air cargo carriers and the main characteristics of each cluster group of airlines. Seven main clusters are defined: Carpet Sellers, Basic Cargo Operators, Strong Regionals, Huge Americans, Large Passenger Wide-body Operators, Premium Cargo Operators and Cargo Stars.

Table 10: Typology and main Characteristics of Cluster Groups

	E.g.	Ethiopian, Brussels	Korean Air, ANA	Saudi, EVA	Delta Air	Qantas	Cathay, SIA	Lufthansa
	Typology	Carpet Sellers	Basic Cargo Operators	Strong Regionals	Huge Americans	Large PAX WB Operators	Premium Cargo Operators	Cargo Stars
Financials	TOT Operating Revenue	Lowest	Medium	Low	Highest	Medium	Medium	High
	TOT Operating Profit	None	Medium	Low/Medium	Highest	Medium	High	High
	Oper. profit/ATK	$0.0016	$0.0408	$0.0271	$0.0294	$0.0304	$0.0671	$0.0371
Product Strategy	Product diff.	Basic Product	Basic Product	Medium Range	Medium range	Medium Range	Broad Range	Broad Range
	Oper. Rev./ATK	$0.6038	$0.6898	$0.6295	$0.6765	$0.5794	$0.8151	$0.8538
	Yield	Low	Medium	Low/Medium	Medium	Low	High	High
Market Strategy	Weight LF	65%	64%	70%	62%	74%	71%	73%
	Capacity Mgt	Low	Low	Medium	Lowest	Highest	Medium	High
	Usage of Hub	Small hub	Strong regional	Small hub	Medium size	Varies	Main hub	Main hub
	Stage length (km) PAXac	886	2125	1640	1968	1956	2515	2311
	Stage length (km) FRac	3013	2082	4305	0	4199	3602	4574
Network Strategy	Unit Cost/ATK	$0.6022	$0.6491	$0.6075	$0.6471	$0.5490	$0.7485	$0.8167
	Unit Cost	Low	Medium	Low	Medium	Lowest	High	Highest
	Avg Fleet size	34	132	96	670	293	190	319
	Freighter usage %ATK	0%/100%	31%	31%	0%	12%	27%	31%
	Km (000) by FRac	0/11498	24503	20902	0	11090	28731	36664
	Avg dist 1 ton PAXac (km)	1921	4200	3889	5981	5113	4297	5845
	Avg dist 1 ton Frac (km)	3661	3949	2593	0	8170	4282	6928

5. BUSINESS LEVEL STRATEGIES WITHIN THE TYPOLOGY

This chapter provides a more in-depth overview of the business level strategies within the typology. Each airline cluster has got its own characterizing features, and similarities and differences in product, market and network strategy. Striking differences and similarities are highlighted. Interesting is to observe in which cluster and on what basis each of the individual airlines from the sample is situated.

To the *'Carpet Sellers'* cluster group belong air cargo carriers such as Ethiopian Airlines, Gulf Air, and Brussels Airlines, but also full cargo carriers such as Polar Air Cargo and Nippon Cargo Airlines. These carriers tend to be smaller carriers each focusing on a niche. Ethiopian Airlines has indeed the strategy to focus on an African network, complemented with freighter cargo flights in and out of Africa. Gulf Air and Brussels Airlines are regional passenger carriers with a limited but geographically focused long haul network. Relatively small cargo-only airlines such as Polar Air Cargo and Nippon Cargo Airlines also belong to this group. Their small size enables them to be flexible where and when needed in their specific niche. Cluster group member Volga-Dnepr airlines focuses on charter flights with Antonov 124's and scheduled flights with Boeing 747's, mainly with outsized or difficult-to-handle cargo loads.

Carpet Sellers are characterized by their small size, generating modest total operating revenue compared to the other cluster groups. Total operating profits are very low, with an average of 0.16 USD cents per ATK (all figures for 2010), while the other cluster members enjoy significantly higher operating profit margins, ranging from 2.71 USD cents (Strong Regionals) to 6.71 USD cents (Premium Cargo Operators) per ATK.

As far as the Carpet Sellers' Product Strategy is concerned, revenues per ATK are on average 60.38 USD cents, while the 'Premium Cargo Operators' cash in an average of 81.51 USD cents and the 'Cargo Stars' an average of 85.38 USD cents per ATK. This yield is low compared to the other clusters. However, yield/ATK figures are even worse, taken into account the relative shorter stage lengths of this cluster's passenger and freighter aircraft, as longer stage lengths tend to generate lower yields/ATK. Revenue is generated by offering a basic standard cargo product, hardly differentiated and aims, mainly capacity driven, 'to fill up the aircraft', hence the name of the cluster 'Carpet Sellers'. Cargo departments at passenger and combination airlines in this cluster are often small departments, attached to the passenger sales teams. Cargo sales departments at the freighter-only airlines within this cluster are of course more dedicated to cargo. The small size of the company, the point-to-point traffic network structure, the lack of sufficient in- and outbound connections and the fixed capacity of the routes flown generate a capacity instead of yield driven attitude within the sales teams. However, due to their flexibility, short-term opportunities can occasionally be seized, resulting in ad-hoc higher yields on particular occasions.

The above mentioned sales efforts and pricing structure generate a weight load factor of 65% which is on the low side compared to the better performing 'Strong Regionals', 'Large Passenger WB Operators', 'Premium Cargo Operators' and 'Cargo Stars'. However, given the operational constraints mentioned before, the 65% weight load factor still is higher than the 'Basic Cargo Operators' (64%) and 'Huge Americans' (62%). Interesting to note is that the weight load factor of the 'Basic Cargo Operators' is almost identical to the 'Carpet Sellers', but that the latter manages to achieve a 68.98 USD cents revenue per ATK while the 'Carpet Sellers' only manage to raise 60.38 USD cents revenue per ATK.

'Carpet Sellers' operate from a small freight hub with limited in- and outbound connecting freight possibilities. Therefore, the airlines have to adapt their strategy to this limitation. Focus is on using some advantages of a small hub such as the congestion-free environment and the availability of ample space for logistical activities. The latter attracts other logistical players that can interconnect and focus on niche markets. The small hub of the 'Carpet Seller' is mainly used by passenger aircraft, used for regional operations (note the very short average stage length of passenger aircraft of 886 km), combined with niche long haul destinations. 'Carpet Sellers' perform either passenger or freighter operations. Freighter-only operators in this cluster operate a relatively short average stage length of 3013 km, implying multiple stops for freighter operations originating from these hubs. This has an adverse effect on the yield and cost structure.

The cost figures, however, are incomplete for this cluster as a number of important airlines in this cluster, such as Etihad Airways, Gulfair, CAL Cargo Airlines and Polar Air Cargo do not supply any cost data and are missing in the data set. However, the average cost can be calculated by using the complete data set on the operating profit. Operating costs per ATK are at 60.33 USD cents per ATK. This is on the lower side of the spectrum compared to the other cluster groups, however, still higher than the Basic Cargo Operators (54.90 USD cents/ATK) but lower than the Premium Cargo Operators (74.85 USD cents per ATK) and the Cargo Stars (81.67 USD cents per ATK).

‘Carpet Sellers’ are relatively small in fleet size, with an average of 34 aircraft in their fleets. Freighter- only companies within this cluster fly an average of 11.498 million km with their freighter aircraft, similar to the ‘Large Wide Body PAX operators’, while other cluster members who are operating freighters fly double or treble these distances. Noteworthy in the network strategy is also that the average distance 1 ton travels on a passenger aircraft (1 921 km) is by far the lowest when compared to the other cluster groups. Set off against the short stage lengths of the passenger aircraft, one could deduct that the longer haul routes are mainly used for cargo sales. The average distance 1 ton travels on a freighter aircraft is 3 661 km, which is more in line with the averages on the other clusters, however on the lower side. As stated above, due to the small freight hub from where the airline operates, multi stops and ‘milk round flying’ are necessary to fill available freighter capacity.

The *‘Basic Cargo Operators’* cluster consists of medium sized carriers such as Korean Air, Qatar Airways, ANA and Turkish Airlines. The airlines in this cluster generate an average operating profit of 4.08 USD cents per ATK, which is the highest but one, compared to the other clusters. Although the weight load factor is on the lower side (64%), the operating revenue of 68.98 USD cents per ATK and the operating cost of 64.91 USD cents per ATK are at a competitive level compared to the other cluster groups. Although product differentiation is limited, and mainly focuses on pushing volume in a fast and reliable way through its extensive route network, the carriers within the cluster manage to achieve higher revenues per ATK compared to their colleagues in the other clusters. Only the ‘Premium Cargo Operators’ and ‘Cargo Stars’ achieve higher yields through a broader product differentiation range with respectively 81.51 and 85.38 USD cents per ATK. Yields are obviously more important than filling up capacity ‘at any price’, which is a basic component of the pricing strategy. Therefore, this is one important feature which differentiates them from the ‘Carpet Sellers’’ pricing strategy.

The airlines in this cluster operate from a strong regional cargo hub such as Seoul, Doha, Tokyo or Istanbul. This hub location generates some additional traffic on the routes of the concerned home carrier. Freighter produced ATK’s (31% of total) is on the same level as the ‘Strong Regionals’, ‘Premium Cargo Operators’ and ‘Cargo

Stars'. The mix of passenger and freighter aircraft is used to balance, reinforce and expand the network originating from the medium sized hub. Remarkable here in the summary of the output of the Cluster Analysis in table 10 is the specific mix of a relatively long stage length of the passenger aircraft (4,200 km) and the relatively short stage length of the freighter aircraft (2,125 km).

With an average size of 132 aircraft, the airlines in this cluster are important airlines in their geographical area, however, still regional players compared to the airlines in most other clusters. The airlines in the clusters 'Premium Cargo Operators', the 'Large PAX Wide Body Operators' and the 'Cargo Stars' are significantly larger than the airlines in the cluster 'Basic Cargo Operators' with an average of respectively 190, 293 and 319 aircraft, hence generating more connections and frequencies. The deployment of freighter operations is therefore mandatory for the 'Basic Cargo Operators' to offset some of these disadvantages.

Some relatively small carriers, with an average of 96 aircraft, such as GOL, Swiss, Saudi and EVA Airways can be categorized in the cluster *'Strong Regionals'.* These airlines operate a strong short and medium haul network from a second tier passenger and cargo hub (Zürich, Taipei, Riyadh ...). This network is supplemented with a long haul network, fed by the short and medium haul routes. While all efforts are done to differentiate both the passenger and cargo product, yields tend to be at the lower end of range, with airlines within the cluster generating average operating revenues of 62.95 USD cents per ATK. The fact that the airline operates from a small hub and needs to use to its full extent the hub-and-spoke system to fill up available capacity generates additional Ton Kilometres for every shipment, hence lowering revenue/ATK. A 70% load factor is relatively high compared to the two previously discussed clusters, but still lower than most of the other cluster groups. The cargo generated to and from the home base is not sufficient to fill up capacity. Significant efforts are made by these teams to attract cargo from outside the typical home base catchment area. Therefore, 'Strong Regionals' typically have at their disposal well equipped, regionally embedded and well trained cargo sales staff.

Due to the relatively competitive disadvantageous position discussed above, 'Strong Regionals' have to be both service and cost focused. Apart from being service focused through product differentiation and service excellence, 'Strong Regionals' tend to be rather cost focused, generating ATK's at an average cost of 60.75 USD cents. Thanks to these low costs, airlines in this cluster group generate average operating profits of 2.71 USD cents/ATK, which is a good performance compared to the other cluster groups' operating profits. A noteworthy aspect of the network build-up is the high freighter usage of 31% with long stage lengths for the freighter operations transporting the main cargo loads from the home base to other large hubs, while regional incoming and outgoing freight tends to be on the belly loads of the passenger aircraft. However, the key indicator showing the average distance 1 ton travels on a passenger aircraft demonstrates that the bulk of the cargo is transported on the long haul passenger routes.

The fact that Cargolux belongs to the 'Strong Regionals' cluster could raise eyebrows as it feels like the odd one out among its cluster 'colleague' group members. Although the commercial strategy of Cargolux is similar to its peers within the group, operational set up is at first sight not similar. However, a regional hub and spoke system is created by trucking routes operating under a Cargolux flight number and airway bill.[3].Moreover, the operational specificities of Cargolux' route network through flying medium haul distances with its 14 Boeing 747's through successive patterns of round-the-world hobs ('milk-round flying') are very similar to the flight output mix of the other members of this cluster. Similarly, Cargolux operates from Luxemburg city, a small regional hub. Moreover, another explaining factor for its membership of the 'Strong Regionals' is that Cargolux' yield, through a well-thought product and pricing differentiation strategy, is higher than the full cargo airlines in the 'Carpet Sellers' cluster, but lower than the combination carriers in clusters 'Premium Cargo Operators' and 'Cargo Stars'.

The strategy model of two important *'Huge Americans'* American Airlines and Delta Airlines justifies the construction of a single cluster. Airlines in this cluster have an average of 670 passenger aircraft which is by far the highest number among the clusters. High operating revenues and a vast ATK output, combined with a medium high yield of 67.65 USD cents/ATK, similar to the 'Strong Regionals', and reasonable average operating profits of 2.94 USD cents/ATK generate high total operating profits.

The air cargo market in the home market USA is heavily dominated by integrators Fed Ex and UPS, operating a dense worldwide ground and air network. Therefore, domestic air cargo is not a focus product for American Airlines and Delta Airlines who

[3] ATK's produced by road transport under a Cargolux flight number are included as 'flights' in the dataset

tend to focus on passenger transport. The weight load factor of 62% is on the low side, and is more seen as a very lucrative by-product of the belly capacity of the regular passenger route network. However, both American Airlines and Delta Airlines realize this and employ fully fledged regional cargo sales teams centrally and at their outstations. In addition, AA Cargo and Delta Cargo offer a differentiated product portfolio. Observing the average stage length of the passenger aircraft of 1 640 km, and the average distance 1 ton of cargo travels on a passenger aircraft, it can be concluded that air cargo travels mainly on the longer haul international routes, where more wide body aircraft are employed, and where less direct competition from the integrators is encountered. Freighters are not employed in the network of the 'Huge Americans'.

The other American carrier in this sample, Continental Airlines, is due to operational differences not part of this cluster group, but is part of the 'Large Passenger Wide-body Operators', which will be further explained below. Continental Airlines is before its ongoing merger with United Airlines, still only about half the size of American Airlines or Delta Airlines. It operates a more internationally stretched network, employs more wide body aircraft, and operates with a longer average stage length. Moreover, it has a higher weight load factor of 73%.

A fifth cluster group is identified as the *'Large Passenger Wide-body Operators'*. Well known, on a worldwide basis operating airlines such as British Airways, China Southern Airlines and Continental Airlines belong to this group. These airlines are large operators as they employ on average 293 aircraft, a significant share of these are wide-body aircraft. Empirical research demonstrated that these operators have a vast cargo capacity in their wide-body belly holds, which are professionally and aggressively sold on the air cargo market. The average weight load factor of this group is with 74% the highest among the group clusters. However, the off-set is that the yield of 57.94 USD cents per ATK is the lowest within the clusters' range. In order to sell the produced capacity professional cargo sales teams are operating from the headquarters and at regional sales offices. Product differentiation is applied, differentiating on a number of express, cool chain, life stock products and oversized goods, similar to the differentiation applied by the 'Strong Regionals' and 'Huge Americans'.

Both the sizeable long haul network and the intensive usage of a high number of wide body aircraft generate a very competitive average unit cost of 54.90 USD cents per ATK. The low yield, combined with the low average unit costs result in average operating profits of 3.04 USD cents per ATK. Remarkable are the very long average distances a ton is transported on passenger and freighter aircraft (5 113 and 8 170 km respectively). Taken into account the 'normal' stage lengths of the passenger aircraft, it can be concluded that the cargo is mainly transported on the long haul wide body aircraft. Freighter aircraft are used for only 12% of the tonnage capacity, which is mainly to balance loads on the network and supply additional ad hoc capacity on a number of routes. In addition, the significant difference between the average stage lengths of the freighter aircraft and the average distance 1 ton flies on a freighter aircraft demonstrates the relatively low weight load factor (around 50%) of the freighters, reinforcing the observation that freighters are mainly used to balance the loads on the network.

The *'Premium Cargo Operators'* cluster is a cluster that stands out because of its high operating profits of 6.71 USD cents / ATK. Well known medium sized passenger and cargo carriers such as Singapore Airlines, China Eastern Airlines, KLM and Cathay Pacific are part of this cluster. The high operating profits are mainly generated by a combination of a high yield of 81.51 USD cents per ATK and a high weight load factor of 71%. One of the key success factors of this winning combination of a high weight load factor and a high yield is the usage of Revenue Management Systems (RMS), previously only used for passenger yield management. However, these RMS are now increasingly introduced in the cargo sales of these airlines for capacity forecasting and allotment planning, and demand forecasting and optimal pricing. All of these airlines in the cluster are known to use RMS for cargo capacity planning and pricing to some extent.

The key indicators of this cluster are similar to the ones in the cluster of the 'Basic Cargo Operators' as they are both very similar in size and operational route performance parameters. However, 'Premium Cargo Operators' operate from a major cargo hub thereby attracting and supplying additional forwarders' traffic in the airlines' network. The airlines of this cluster fly from a major cargo hub such as Singapore, Shanghai, Amsterdam or Hong Kong. This fact, plus the usage of RMS and the broader range of high yield products offered, generate a significantly higher yield of 81.51 USD cents per ATK compared to 68.98 USD cents per ATK generated by the 'Basic Cargo Operators'. The higher operational costs of 74.85 USD cents per ATK are partly caused by the higher operational costs incurred due to operating out of a major hub and the higher costs associated with offering higher yield products to their customers.

ATK's are produced by a balanced mix of belly hold (73%) and freighter capacity (27%). Remarkable is the high average stage lengths of the passenger aircraft (2 515 km), indicating that the gravity of the networks of these airlines is on the longer haul routes.

A final cluster can be named the *'Cargo Stars'*, with as sole members within this cluster the large passenger and cargo carriers Lufthansa, Emirates and Air France[4]. When the highest operating profits per ATK among the clusters would be taken into account, the previously discussed cluster 'Premium Cargo Operators' would be called the 'Stars'. However, due to fact that the 'Cargo Stars' are almost double in size, generate an even higher yield and their cargo departments operate as independent Business Units, this cluster was awarded the name 'Star'.

High operating revenues of 85.38 USD cents per ATK and high weight load factors of 73% indicate that cargo strategy is a major part of their overall yield management at these clusters' airlines. Indeed the mentioned airlines created their own branded cargo division, producing independently the freighters' capacity and selling the cargo capacity of their respective sisters' airlines. These divisions have a full management structure managing their own P&L environment, where they are fully responsible for the revenues and costs of the division, creating full transparency on the profit contribution of the cargo division. Often the freighter aircraft are operated by this entity, however, with the pilot crew hired in from the sister airline. A number of products (express, cool chain, life stock, etc…) are offered to enhance the yield. Moreover, often warehousing, trucking, and associated 3PL activities are offered by the cargo division.

The more expensive operating environment at the main hubs generates a high unit cost of 81.67 USD cents per ATK. Operating from a main hub, such as Frankfurt, Dubai or Paris, freighters are intensively used with an average of 36.6 million km a year and transport about 31% of the tonnage. Remarkable is also the very high average stage length (4 574 km) of the freighter aircraft and the very long distance a ton of cargo is transported on a freighter aircraft (6 928 km). This demonstrates that

[4] Up to now, AF en KLM still report separate operational output data, and have separate, however closely working together, operational departments. Plans are developed at Air France under the 'Transform' plan to merge the cargo departments of Air France, KLM and Martinair into one single operating entity.

the gravity of the transported cargo is on the longer haul sectors for both passenger and freighter aircraft. Operating profit is at 3.71 USD cents per ATK, lower than the ‘Premium Cargo Operators’ and ‘Basic Cargo Operators’, but higher than the operating profits at the other cluster groups.

6. CONCLUSION

This paper dealt in the first sections with the business level strategies of air cargo carriers and more specifically focused on the definition of a typology of strategies for both combination and full cargo airlines. Building blocks of the global strategic framework of air cargo carriers were grouped into a product, market and network part of the business level strategy. Subsequently, indicators and key performance indicators have been identified and defined for the most significant components in the above mentioned strategy framework. This paper explained the gradually built up results of a research on strategy typologies through a K-means Cluster Analysis on the data of 2010 which have been collected for these indicators and key performance indicators for a representative sample of 47 air cargo carriers.

The final section of this paper presented the final results of this research which generated a typology of seven representative clusters of air cargo operators’ strategy models. The following typology of strategy models was identified: the Carpet Sellers, the Basic Cargo Operators, the Strong Regionals, the Large Wide Body PAX Operators, the Huge Americans, the Premium Cargo Operators and the Cargo Stars, each with their own characterizing features and similarities and differences among them. Interesting was to observe in which cluster and on what basis each of the individual airlines from the sample of 47 air cargo carriers were situated. Striking differences and similarities were highlighted. Moreover, both the strategic rationales and the driving factors behind some strategic choices were further elaborated for a number of air cargo carriers within each typology group.

While some research has been done on passenger airlines strategy, the strategies of air cargo carriers have hardly been researched. The use of a cluster analysis to group the strategy models of a number of air cargo carriers is also a novel feature of this research. Our findings suggest the clear existence of different strategy models and demonstrate the differing degree of focus on air cargo strategy development and deployment among the air cargo carriers’ population.

REFERENCES

- Air Cargo Management Group (2006), *International Air Freight and Express Industry Performance Analysis December 2006*, Seattle: ACMG.
- Air Cargo Management Group (2011), *ACMG Workshop on Air Cargo, Express & Freighter Aircraft*. Atlanta, May 2011.
- Air Transport World (2011), *2011 World Airline Report*, July 2011.
- Boeing (2008), *World Air Cargo Forecast 2008-2009*, Seattle: Boeing.
- Chiavi, R. (2005), *Air Freight Development supporting the Strategy of Global Logistics Companies. In Delfmann, Baum, Auerbach and Albers e.a. (ed.) Strategic Management in the Aviation Industry (ed. Delfmann e.a.),* Aldershot: Ashgate, 489-515.
- Dewulf, Vanelslander and Van de Voorde (2009) Assessing the features, key drivers and current trends in the air freight industry and their impact on the regional supply chain. *Metrans 3rd National Urban Freight Conference*. Long Beach, 21-23 October.
- Dewulf, Vanelslander and Van de Voorde (2010) Key factors influencing the management strategies of air cargo carriers. *14th Air Transport Research Society Conference*. Porto, 6-9th July.
- Dewulf, Meersman and Van de Voorde (2011a) Key indicators of Management Strategies for Air Cargo Carriers. *15th Air Transport Research Society Conference*. Sydney, 29th June-3rd July.
- Gardiner, Ison and Humphreys (2005), 'Factors influencing cargo airlines' choice of airport: An international survey', *Journal of Air Transport Management*, 11, 393-399.
- Herman, F. and E. Van de Voorde (2007), 'Bijdrage tot de economische analyse van het full-freighter luchtvrachtvervoer', *Tijdschrift Vervoerswetenschap*, 42/4, 16-23.
- International Air Transport Association (2011), *World Air Transport Statistics*, 55th edition, Montréal: IATA.
- Kadar and Larew (2004), 'Securing the Future of Air Cargo', *Mercer on Travel and Transport*, Fall 2003/Winter 2004, 3-9.
- Meersman, H., E. Van de Voorde and T. Vanelslander (2008), 'The Air Transport Sector after 2010: A Modified market and Ownership Structure', *European Journal of Transport and Infrastructure Research*, 8-no. 2, 71-90.
- Vertannes, D., *Interview on 4th June 2012 with Wouter Dewulf on 'Validation of results on cluster analysis',* IATA, Geneva.

DOES PERTAINING TO A GLOBAL STRATEGIC ALLIANCE IMPROVE THE BOTTOM LINE?

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ABSTRACT

This study researched whether pertaining to a global strategic alliance brought significant benefits to the 'bottom line' of allied airlines. The study used two groups: a group of airlines which had joined one of three global alliances against a control group of airlines which had not joined any alliances. The research compared the net return of those two groups before and after airlines joined their alliances (or equivalent measure), as well as their relative net performance both in the short-term and in a longer term. Results showed a sensible deterioration in net profitability for the alliance group and a perceptible improvement in net profitability for the non-alliance group. The latter also differed from the former in having a positive relative net performance in the short-term.

Keywords: global strategic airline alliance, airline profitability, ICAOData.

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1. INTRODUCTION

Research done on airline strategic alliances can be grouped into two broad streams. One stream focuses on alliances and assesses the factors contributing to the success and/or failures of the same. These studies use measurements such as alliance stability/instability and mortality/longevity to determine alliance success (for example, Kogut, 1989; Hamel, 1991; Blodgett, 1992; and Li, 2000; Iatrou and Alamdari, 2005; Gudmundsson and Lechner, 2006). The other stream focuses on alliances' members and assesses the impact of alliances on member airlines. They employ airline performance variables such as market share, market value, revenue, profitability, and productivity, to evaluate the impact of alliances on airline performance (for example, Park and Cho, 1997; Chan, Kensinger, Keown and Martin, 1997; Das and Teng, 1998; Anand and Khanna, 2000; and Oum, Park, Kim and Yu, 2004).

A number of those studies have reported that joining global strategic alliances helps increase airlines' profitability (Iatrou and Alamdari, 2005; Oum and Zhang, 2001; Oum, Park and Zhang, 2000). Yet other studies have concluded that alliances are not necessarily profitable for their members (Morrish and Hamilton, 2002; Bilotkatch and Hüschelrath, 2011), even when allied airlines are in a better position to increase functional efficiency and to benefit from economies of scale (Amankwah-Amoah and Debrah, 2011; Flightglobal, 2006).

Recent research carried out on a decade-worth of net returns has found that airlines, at best, tend not to become more profitable or, at worst, may even lose profitability after joining an alliance. This trend has been reported both when using nominal currency (Perezgonzalez and Lin, 2010) as well as when controlling for inflation (Perezgonzalez and Lin, 2011a). The research has also found that not only alliance members had lost profitability (or had not managed to increase it, overall) but that non-allied airlines had performed much better and remained profitable over a relatively similar period of time (Perezgonzalez, 2011b).

The primary focus of this study was to consolidate above research and to ascertain whether pertaining to a global strategic alliance has brought significant benefits to the 'bottom line' of allied airlines when compared against airlines which had not joined any alliance.

2. EMPIRICAL CONTRIBUTION

2.1. Methods

The source of data for this research was the financial database compiled by the International Civil Aviation Organization, ICAOData, which is the result of an aviation data management cooperation between ICAO and Air Transport Intelligence (ATI)[2]. The database contains data for both air carriers and airports, including financial, traffic, personnel, fleet, and on-flight origin and destination data since 1973. Reporting to ICAOData is done on a voluntary basis, and data are often incomplete or missing (Perezgonzalez, 2011a).

This research focused on airlines' proficiency over a relatively long period of time. Because of missing data, however, we ended using the entire population of twenty-one airlines which had provided relevant data to ICAOData over a period of eleven consecutive years centred on the year they first joined their alliance. This population comprised fifteen airlines which had joined one of three global strategic alliances (Star Alliance, Oneworld or SkyTeam), and six airlines which were not in an alliance at about the same time. The former airlines comprised our 'research' group and the latter comprised our 'control' group.

The data of interest were net returns during eleven consecutive years centred on the year airlines joined their alliances, and around the year 2000 for the non-alliance group. Net returns covered the period ranging from five years before to five years after airlines joined an alliance (or between 1995 and 2005 for the non-alliance group). All nominal values were corrected for inflation and reported as referential US dollars, rUSD (which are constant dollars standardized to 2010 nominal values – Perezgonzalez, 2011b).

2.2. Results

Table 1 provides the most telling results, although a breakdown of the same is provided in Tables 2 and 3. We will, thus, introduce the latter, before commenting on the former.

[2]ICAO is a specialized agency of the United Nations. It was created in 1944 to promote air safety and the orderly development of international civil aviation throughout the world. ATI provides a service that delivers air transport news and data.

Table 1: Percentage of Airlines that Gained/Lost Net Performance

	Medium-term (10yr)		Short-term (8yr)	
	% gained	% lost	% gained	% lost
NON-ALLIANCE GROUP	50	50	66	33
Star Alliance	14	86	14	86
Oneworld	40	60	20	80
SkyTeam	33	66	0	100
ALLIANCE GROUP	27	73	13	87

Values rounded to the nearest percentage. (Table adapted from Perezgonzalez, 2012, 2011a, and Perezgonzalez & Lin, 2011b)

Table 2 provides a breakdown of airlines' net returns for the five-year period and three-year period immediately before joining an alliance and the five-year period immediately after joining an alliance (the joining year was excluded from all computations). Net returns for the non-alliance group show results before and after the year 2000. We can observe that the overall pattern of results has been for the alliance group (and any subgroups) to improve performance the closer they got to joining an alliance but to lose profitability after doing so. In comparison, the non-alliance group evolved almost the opposite trend, having low or a deteriorating profitability in the years prior to 2000, but showing a substantive gain after that year.

In Table 3, the trend discussed above is more obvious. The table presents measures of relative performance, which are changes in profitability from one period to the next instead of overall profitability. The medium-term column thus subtracts five years' profitability after joining an alliance from five years' profitability prior to doing so. The short-term column subtracts five years' profitability after joining an alliance from three years' profitability prior to doing so. Results show that most allied airlines lost net performance after joining an alliance, this being more acute in the short term. The non-alliance group, however, showed an increase in net performance after 2000 both in the short and medium term.

Back in Table 1, we calculated the percentage of airlines which gained or lost relative performance (gain/loss ratios). Results are compelling: in the short-term, 66% of the non-allied airlines gained in net performance, although this reduces to 50% in the medium term. Even so, this group is ahead of all allied airlines: 20%-40% of Oneworld airlines gained profitability, 0%-33% of SkyTeam airlines gained profitability, and 14%-14% of Star Alliance airlines gained profitability in the short and medium term, respectively. Overall, only 13% to 27% of airlines in the alliance group showed a gain in relative net performance after joining an alliance, while 87% and 73% of them lost net performance in the short and medium term, respectively.

Table 2: Average Net Returns per Airline, Alliance and Group

NON-ALLIANCE GROUP			
Not in alliance§	5 years earlier	3 years earlier	5 years later
Air India	-72,946	-44,207	17,960
Turkish Airlines	-8,141	-41,461	49,975
Air Europa	6,927	3,434	12,897
Icelandair	10,364	8,051	7,134
Malaysian Airlines	-5,175	-109,388	-57,911
Virgin Atlantic	107,916	135,258	21,378
Group's M (SD)	6,404 (65,119)	-8,052 (82,001)	8,572 (35,797)
ALLIANCE GROUP			
Star Alliance§	5 years earlier	3 years earlier	5 years later
Lufthansa	98,414	321,463	577,231
Thai Airways	160,367	184,690	156,270
BMI	16,411	22,907	-2,017
SAS	179,559	406,672	153,725
Air Canada	-123,536	114,567	-218,633
Singapore Airlines	843,124	812,691	500,457
United	-43,164	429,484	-782,943
Alliance's M (SD)	161,597 (319,662)	327,496 (261,606)	54,870 (460,332)
Oneworld§	5 years earlier	3 years earlier	5 years later
Iberia	-76,870	196,892	162,674
Cathay Pacific	375,087	296,009	477,791
Finnair	79,560	92,479	41,532
British Airways	803,854	795,527	197,681
American Airlines	794,352	1,093,144	-1,476,780
Alliance's M (SD)	395,196 (402,866)	494,810 (429,704)	-119,420 (775,423)
SkyTeam§	5 years earlier	3 years earlier	5 years later
Air France	61,241	360,435	259,510
Czech Airlines	14,801	25,656	8,630
Delta	1,093,796	1,464,375	-2,423,041
Alliance's M (SD)	389,946 (609,994)	616,822 (752,847)	-718,300 (1,481,670)
Group's M (SD)	285,133 (397,029)	441,133 (420,897)	-157,861 (816,512)

* Mean returns. All values in thousands of referential USD (rUSD). (Table adapted from Perezgonzalez, 2012, 2011a, and Perezgonzalez & Lin, 2011b)

Table 3: Relative Performance per Airline, Alliance and Group

NON-ALLIANCE GROUP		
Not in alliance§	Medium-term	Short-term
Air India	90,905	62,167
Turkish Airlines	58,116	91,435
Air Europa	5,971	9,464
Icelandair	-3,230	-917
Malaysian Airlines	-52,736	51,477
Virgin Atlantic	-86,538	-113,880
Group's M (SD)	1,303 (74,015)	16,624 (72,493)
ALLIANCE GROUP		
Star Alliance§	Medium-term	Short-term
Lufthansa	478,817	255,768
Thai Airways	-4,097	-28,421
BMI	-18,429	-24,924
SAS	-25,835	-252,947
Air Canada	-95,097	-333,200
Singapore Airlines	-342,667	-312,234
United	-739,779	-1,212,427
Alliance's M (SD)	-106,727 (370,651)	-272,626 (463,509)
Oneworld§	Medium-term	Short-term
Iberia	239,544	-34,218
Cathay Pacific	102,704	181,782
Finnair	-38,028	-50,947
British Airways	-606,172	-597,845
American Airlines	-2,271,132	-2,569,924
Alliance's M (SD)	-514,617 (1,033,280)	-614,231 (1,130,520)
SkyTeam§	Medium-term	Short-term
Air France	198,270	-100,924
Czech Airlines	-6,170	-17,026
Delta	-3,516,837	-3,887,416
Alliance's M (SD)	-1,108,200 (2,088,400)	-1,335,100 (2,210,750)
Group's M (SD)	-442,994 (1,067,800)	-598,994 (1,151,040)

* Mean returns. All values in thousands of referential USD (rUSD). § Oneworld airlines joined in 1999, most Star Alliance airlines joined in 1997 and some in 2000, while most SkyTeam airlines joined in 2000 and one in 2001; the year 2000 is used for non-alliance airlines. (Table adapted from Perezgonzalez, 2012, 2011a, and Perezgonzalez & Lin, 2011b)

3. SUMMARY AND CONCLUSIONS

The results obtained in this research are eminently descriptive. They are also limited to a particular measure of financial performance only, which may be but a small token in the universe of reasons why airlines join an alliance. Even so, these results appear to be coherent with conclusions in the scholarly literature such as that strategic alliances have no significant overall impact on airlines' profitability (Oum, Park, Kim and Yu, 2004) and that airlines may have been better off by not joining an alliance at all (Perezgonzalez, 2011a). Indeed, this study found that only 27% of airlines in an alliance increased their net performance during the ten-year period before and after joining their alliance, while 50% of non-allied airlines did so, a sensible difference. This study further suggests that alliances may not even help individual airlines preserve, at least, their margins, which some airlines may expect when joining the alliance (Morrish and Hamilton, 2002; Bilotkatch and Hüschelrath, 2011). Therefore, the evidence here described supports the conclusion that pertaining to a global strategic alliance has not helped airlines improved their bottom line, at least not at the time of alliance formation. This conclusion will hardly affect airlines' strategies at present, but it may serve as a benchmark for future research, research focused on ascertaining the longitudinal profitability of airlines and airline alliances in the competitive world of international aviation.

REFERENCES

- Amankwah-Amoah, J. and Debrah Y.A. (2011). The Evolution of Alliances in the Global Airline Industry: A Review of the African Experience. *Thunderbird International Business Review*, 53(1), 37-50.
- Anand, B. and Khanna, T. (2000). How Entrepreneurial Firms Can Benefit from Alliances with Large Partners. *The Academy of Management Executive*, 15(1), 139-148
- Bilotkatch, V. and Hüschelrath, K. (2011). Antitrust Immunity for Airline Alliances. *Journal of Competition Law & Economics*, 7(2), 1-46.
- Blodgett, L.L. (1992). Factors in the Instability of International Joint Ventures: an Event History Analysis. *Strategic Management Journal*, 13(6), 475-481.
- Chan, S. H., Kensinger, W. J., Keown, J. A. and Martin, D.J. (1997). Do Strategic Alliances Create Value? *Journal of Financial Economics*, 46(2), 199-221
- Das, T.K. and Teng, B. S. (1998). Between Trust and Control: Developing Confidence in Partner Cooperation in Alliances. *The Academy of Management Review*, 23(3), 491-512.
- Flightglobal (2006). *Oneworld Membership Gains Carriers a Cool $900 Million*. Available from: http://www.flightglobal.com/articles/2006/06/04/207011/oneworld-membership-gains-carriers-a-cool-900-million.html (accessed on 4/07/2011).

- Gudmundsson, V. S. and Lechner, C. (2006). Multilateral Airline Alliances: Balancing Strategic Constraints and Opportunities. *Journal of Air Transport Management*, 12(3), 153-158.
- Hamel, G. (1991). Competition for Competence and Inter-Partner Learning within International Strategic Alliances. *Strategic Management Journal*, 12(S1), 83-103.
- Iatrou, K. and Alamdari, F. (2005). The Empirical Analysis of the Impact of Alliances on Airline Operations. *Journal of Air Transport Management*, 11(3), 127-134.
- Kogut. B. (1989). A Note on Global Strategies. *Strategic Management Journal*, 10(4), 383-389.
- Li, Z.F.M. (2000). Distinct Features of Lasting and Non-Lasting Airline Alliances. *Journal of Air Transport Management*, 6(2), 65-73.
- Morrish S.C. and Hamilton R.T. (2002). Airline Alliances – Who Benefits? *Journal of Air Transport Management*, 8(6), 401-407.
- Oum, T.H., Park, J., Kim, K. and Yu, C. (2004). The Effect of Horizontal Alliances on Firm Productivity and Profitability: Evidence from the Global Airline Industry. *Journal of Business Research*, 57(8), 844-853.
- Oum, T.H., Park, J.H. and Zhang A. (2000). *Globalisation and Strategic Alliances: the Case of the Airline Industry*. London: Elsevier Science.
- Oum, T.H. and Zhang, A. (2001). Key Aspects of Global Strategic Alliances and the Impacts on the Future of Canadian Airline Industry. *Journal of Air Transport Management*, 7(5), 287-301.
- Park, J.H. and Cho, D.S. (1997). The Effect of Strategic Alliance on Performance. A Study of International Airline Industry. *Journal of Air Transport Management*, 3(3), 155-164.
- Perezgonzalez, J.D. (2011a). A Comparative Study of the Net Profitability of Airlines in Global Strategic Alliances and a Group of Airlines not in an Alliance. *Aeronautica*, 2, 1-5.
- Perezgonzalez, J.D. (2011b). Referential Currency (r). *Journal of Knowledge Advancement & Integration*, 2011, 12-14.
- Perezgonzalez, J.D. (2012). Airlines' Profitability and Relative Net Performance. *Journal of Aviation Management*, in press.
- Perezgonzalez, J.D. and Lin B. (2010). The Net Profitability of Airline Alliances, an Empirical Study. *Aviation Education and Research Proceedings*, 2010, 43-48.

- Perezgonzalez, J.D. and Lin B. (2011a). The Net Profitability of Airline Alliances Using Referential Dollars. *Aviation Education and Research Proceedings*, 2011, 63-65.
- Perezgonzalez, J.D. and Lin, B. (2011b). Comparing the Net Profitability of Airline Alliances Against that of Airlines not in an Alliance. *Aviation Education and Research Proceedings*, 2011, 66-68.