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The mission of the *Journal of Air Transportation* (JAT) is to provide the global community immediate key resource information in all areas of air transportation. The goal of the Journal is to be recognized as the preeminent scholarly journal in the aeronautical aspects of transportation. As an international and interdisciplinary journal, the JAT will provide a forum for peer-reviewed articles in all areas of aviation and space transportation research, policy, theory, case study, practice, and issues. While maintaining a broad scope, a focal point of the journal will be in the area of aviation administration and policy.

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The JAT was conceptualized to fulfill an international void of scholarly publications in this area as identified by the primary organizers. It is envisioned that aviation leaders will utilize the JAT as a key decision-making tool. Scholarly rigor and standards will be uncompromised with regular evaluation by the Editorial Board and Panel of Reviewers.

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The Editors

Brent D. Bowen

Dr. Brent Bowen is Director and Distinguished Professor, Aviation Institute, School of Public Administration, University of Nebraska at Omaha, and the University's Director of Aviation and Transportation Policy and Research. Bowen attained his doctorate in Higher Education and Aviation from Oklahoma State University and a Master of Business Administration degree from Oklahoma City University. His Federal Aviation Administration certifications include Airline Transport Pilot, Certified Flight Instructor (Gold Seal), Advanced Instrument Ground Instructor, Aviation Safety Counselor, and Aerospace Education Counselor. Dr. Bowen's research on the development of the national Airline Quality Rating is regularly featured in numerous national and international media, as well as refereed academic publications. Dr. Bowen has in excess of 300 publications, papers, and program appearances to his credit. His research interests focus on aviation applications of public productivity enhancement and marketing in the areas of service quality evaluation, forecasting, and student recruitment/retention in collegiate aviation programs. He is also well published in areas related to effective teaching and has pioneered new pedagogical techniques. Dr. Bowen has been recognized with awards of achievement and commendation from the American Marketing Association, American Institute of Aeronautics and Astronautics, Federal Aviation Administration, Embry-Riddle Aeronautical University, W. Frank Barton School of Business, Travel and Transportation Research Association, World Aerospace Education Association, and others.

Igor Kabashkin

Dr. Igor Kabashkin is Vice Rector of the Transport and Telecommunications Institute, Latvia, and a Professor in the Aviation Maintenance Department and member of the Technical Committee on Transport of the European Commission for Cooperation in the Field of Scientific and Technical Research. Kabashkin received his Doctor Degree in Aviation from Moscow Civil Engineering Institute, a High Doctor Degree in Aviation from Moscow Aviation Institute, and a Doctor Habilitus Degree in Engineering from Riga Aviation University and Latvian Academy of Science. His research interests include analysis and modeling of complex technical systems, information technology applications, reliability of technical systems, radio and telecommunication systems, and information and quality control systems. Dr. Kabashkin has published over 274 scientific papers, 19 scientific and teaching books, and holds 67 patents and certificates of invention.

Guest Editor

Sveinn Vidar Gudmundsson earned his Bachelor of Science, Master of Business Administration and Master of Science (Systems) degrees from the Florida Institute of Technology in Melbourne, Florida and a Ph.D. from Cranfield University, UK. He has held positions in industry with an airline and a credit card company as marketing manager. He is a Professor of Strategy and Director of CERMAS at Toulouse Business School, France and formerly Assistant Professor Transport and Logistics, University Maastricht, the Netherlands. His current research clusters around qualitative and quantitative performance forecasting methods, electronic markets in aerospace, logistics and transport, firms' entry and exit in deregulated markets, and alliances in the airline industry. He is the author of *Flying Too Close to the Sun: The Success and Failure of the New-Entrant Airlines* (Ashgate, 1998). His articles have appeared in: *Journal of Air Transportation, Transportation Research E, European Business Journal, International Journal of Logistics Management, International Journal of Physical Distribution and Logistics Management, Journal of Air Transport Management* and various trade journals such as *Cargovision*.

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JOURNAL OF AIR TRANSPORTATION WORLD WIDE

Scenarios of the Future of Air Transportation

Editorial by Guest Editor
Sveinn Vidar Gudmundsson

The world aviation community is facing significant challenges for the future given the present rate of growth of air travel. Challenges that raise the question whether change in technology and economic and social expectations will be gradual or discontinuous. Facing the long-term future, there are not many constants we can name except change itself. The scenario process can be an excellent approach to visualize an uncertain future. With current pressures on our air transportation system, we can expect a rather different experience for air travelers in twenty years time from what we know now. Yet, there is relatively little systematic research in this domain to allow airlines and the policymakers to assess strategic options given different possible future directions. The scenario process used for policy formulation in aviation must follow rigorous methodology in order to generate the necessary debate and commitment to advancement. It needs to be global, local, comprehensive, analytically sound, and diverse with a range of possible futures.

We can look at future scenarios for air transportation on three axes: society, economy, and environment. Some of the driving forces playing along the three scenario axes counter each other, but can be reconciled through technological advancement, politics, and perhaps change in social values. Environmental pressures will mount while technological improvements need increasingly higher investment to push the envelope of noise and emissions to an ever lower level in meeting societal expectations for quality of life and more cost-effective aircraft for airlines. These objectives seem irreconcilable in terms, although progress must be made and will be made. We make the issues mentioned above the focal point in what follows.

In this special issue, we present six articles spanning several important areas linked to the theme of *scenarios of the future of air transportation*. The articles can be divided into three sub themes. The first theme covers *scenarios for a future large passenger aircraft configuration,* the second theme deals with *future perspectives on airline profitability,* and the final theme covers the *sustainability of the air transportation system.* All three themes are highly related and intertwined. The first two articles draw up future scenarios: a future blended wing-body passenger service configuration and a market-based future perspective for European air transportation. The third article gives a perspective on fleet standardization assessment. The fourth article discusses the impact of seat comfort on passenger choice of an airline. The final two articles explore the constraints of growth from two perspectives: 1) how to create an approach to assess the sustainability of the air transportation system; and 2) a case study for future requirements in runway capacity in a highly constrained air transportation system and possible approaches to de-peak the demand in a scenario of no additional runway capacity.

Eelman, Schmitt, Becker and Granzeier use the classic scenario process to build three visions for a new generation of aircraft—the blended wingbodies (BWB). The BWB would accommodate demand in congested airports by offering an even larger

seat capacity and greater efficiency than known today on several fronts. In one of the scenarios, the authors briefly discuss the possibility of a new integration between air terminal and aircraft by utilizing passenger containers that can be transported straight into the aircraft providing a degree of seamlessness that could revolutionize airport crowd management and passenger comfort by reducing walking distances. Overall, the authors give an excellent insight into an innovative approach to envision possible passenger configuration on a BWB.

Jarach in his article addresses the difficult financial situation of the legacy airlines and proposes a market-based view to cope with the situation. He asserts that there is still a quasi-protective airline environment in Europe, characterized by government ownership in many countries, national pride and interference with free market forces by national governments. He proposes five pillars of action that according to the article should facilitate the transition of legacy carriers towards a sustainable operating model in a stronger but streamlined European industry.

Janic proposes an indicator system to measure the sustainability of the air transportation system. The indicator system is composed of four dimensions: operation, economic, social and environmental performance. The systems proposed has fifty-eight indicators of which twenty-six indicators have been analyzed for the US market. He points out the difficulty in finding good data for European air transport compared to the US which has extensive and transparent data programs that are usually mandatory for airlines. Janic concludes, based on the partial analysis, that in general the air transportation system has shown traits of sustainability. He points out the impact of terrorist acts on the economic and operational dimensions.

Lu and Tsai present a logic model examining the impact of increased seating space on passenger preference. They conclude, based on their model, that airlines should place more emphasis on seat comfort. They found this element to be related to passenger preference in selecting an airline given the same fare on all competing carriers.

Pan and Santo suggest a fleet standardization index in order to pave the way for deeper understanding of this issue in airline management. The authors argue that fleet standardization has economical, operation and route planning advantages for airlines. Using the index, the authors point out that airline aircraft fleets can be compared and changes analyzed in terms of potential performance impact.

Urbatzka and Wilken analyze the traffic situation in German airports according to long-term scenario based forecasts. The authors conclude that in less than 10 years time Germany will capacity needs will be equivalent to six new runways in the largest airports which will most likely not be provided. As a consequence, alternative strategies are needed and the authors describe a de-peaking approach using a supply-spreading approach characterized by increased utilization of secondary airports. This approach is developed and explained in detail in this paper.

This special issue of the *Journal of Air Transportation* was designed to provide the reader with additional knowledge and insight pertinent to our many possible futures and some of the ways that are needed to cope with future growth. What is more, it is our hope that this special issue will stimulate further research in aviation using a rigorous application of the scenario process.

Sveinn Vidar Gudmundsson
CERMAS Research Center & Department Strategy

Toulouse Business School
Toulouse, France

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VOLUMES

Volume 9
Number 2

Air Transport Research Society Special Edition

Guest Editorial - Sveinn Vidar Gudmundsson

Future Requirements and Concepts for Cabins of Blended Wing Body Configurations—A Scenario Approach

Future Scenarios for the European Airline Industry: A Marketing-Based Perspective

An Application of the Methodology for Assessment of the Sustainability of the Air Transport System

Modeling the Effect of Enlarged Seating Room on Passenger Preferences of Domestic Airlines in Taiwan

Developing a Fleet Standardization Index for Airline Pricing

Future Airport Capacity Utilization in Germany: Peaked Congestion and/or Idle Capacity)

Return to Volumes

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Journal of Air Transportation **Vol. 9, No. 2 - 2004**

FUTURE REQUIREMENTS AND CONCEPTS FOR CABINS OF BLENDED WING BODY CONFIGURATIONS—A SCENARIO APPROACH

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Technische Universitat Munchen

Axel Becker
Society and Technology Research Group
DaimlerChrysler

Werner Granzeier
iDS, industrial Design Studio

ABSTRACT

The strong influence of unpredictable factors on the development of future concepts for cabins of Blended Wing Body (BWB) aircraft favors the methodology of scenario techniques. The scenario process performed at Technische Universitat München together with Airbus Deutschland GmbH, DaimlerChrysler Society and Technology Research Group and industrial Design Studio comprises the development of three different scenarios, the implication of specific requirements and the realization of preliminary cabin concepts. On the basis of current cabin standards of the A380, new standards for the BWB cabin designs were quantitatively derived for each scenario. According to these inputs, two-dimensional cabin layouts and specific system solutions have been developed and sketched to visualize the concepts. In a final step, specific requirements and technologies have been evaluated in all scenarios to identify their compatibility in the respective future environments.

Stephan Eelman received a Bachelor's degree in Aerospace Engineering from the Technische Universität München (TUM) in 1997. In the course of his subsequent graduate studies, focusing on commercial aircraft and its interfaces in the air traffic system, he was granted a scholarship at Delft University of Technology, the Netherlands, before receiving a Master's degree in Aeronautical Engineering in June 2000. Continuing at MTU Aero Engines in the Market-Technology-Department, he took an opening as research scientist in 2001 and since 2002 is scientific assistant at the Institute of Aeronautical Engineering, TUM. Since then he has been involved in several scenario projects with partners from aerospace industry.

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INTRODUCTION

With a basic scenario of a strong aviation business growth of around 4.7% per year in the next thirty years, passenger volumes will multiply by a factor of at least two-and-one-half until the year 2020 (Airbus, 2002) and almost quadruple by the year 2030 from today's level. Taking into account that capacity in the air and at major and hub airports already is evolving as a limiting factor and that airline efficiencies will have to improve from current levels, aircraft with higher productivity yields may play a major role in the future of the aviation system. This could lead to an additional concentration of large passenger flows through hub airports with little infrastructure capacity on the airport airside (e.g. runways, taxiways, aprons, parking positions) available, especially with regard to long-range routes with significantly longer turn-around times.

Dieter Schmitt completed his mechanical engineering studies in 1968 at Technical University in Darmstadt and continued at the Institute of Aeronautics in Darmstadt as a scientific assistant of Prof. X. Hafer until 1975. He received his Doctorate in 1976, already being involved as a flight engineer at MBB (Messerschmitt Bölkow Blohm) in Hamburg in the tailplane design for A300 B10 and A310 until 1980. As a manager of Aerodynamics he coordinated all aerodynamic aspects of Airbus Industries in Toulouse, France. He served as general manager of Research and Technology, vice president of Future Projects, and chief engineer. In 1996 he was nominated Lead Professor of the TUM Institute of Aeronautical Engineering. Since 2002 he has been vice president of Research and Technology at Airbus.

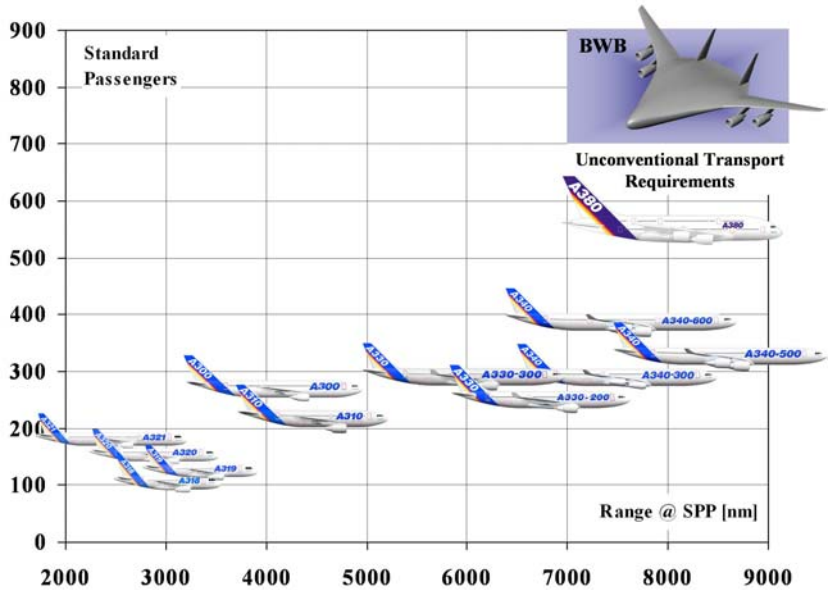
Axel Becker, certified engineer, studied from 1990 to 1996 at the Institute of Aeronautics and Astronautics of the Technische Universität Berlin, putting the main emphasis of his studies on systems dynamics; civil aviation economy and policy; and corporate and innovation management. Since 1991, he has participated in the Society and Technology Research Group of the DaimlerChrysler AG in Berlin. In this he has been co-responsible, among other things, for the conception, moderation and methodical monitoring of different projects such as Civil Aviation and Alternative Drivetrains. Furthermore he is working on the systematic analysis of business and product environments, strategic development and assessment and the further development and application of the scenario method in the context of corporate decision and product development processes.

Werner Granzeier finished his studies in Industrial Design at the Bergische Universität GHS in Wuppertal. He started as a designer at MBB (Messerschmitt Bölkow Blohm) and later at VFW-Fokker and Airbus. He developed cabins of commercial aircraft, among which for example the A320 basis cabin. In 1984 he founded his own company iDS, industrial Design Studio, in Hamburg and was involved with the design of the Boeing 717 cabin and later the Fairchild Dornier 728Jet program as well as projects together with Airbus Cabin Research. From 1989 on he was assigned as Professor at the Hamburg University of Applied Sciences in the Department of Automobile and Aeronautical Engineering and completed here several exterior and interior designs of aircraft. He is member of DGLR (Deutsche Gesellschaft für Luft- und Raumfahrt) and AIAA (American Institute of Aeronautics and Astronautics).

To cope with these demanding qualities of future air travel, airlines require new aircraft configurations to ensure and improve operational efficiency, productivity and customer value in a highly competitive market environment.

The conventional aircraft configuration is reaching its optimum and even scaling effects with bigger airplanes do not provide the potential for leap improvements. Though claiming superior economics over current large airplanes, the introduction of the Megaliner A380 seems to be the upper limit of size for conventional airplanes and is a probable transition to a next generation of aircraft, which combine extremely low fuel burn with high capacity, high environmental compatibility, low operating costs, and operational flexibility for airlines (see Figure 1).

Figure 1. Airbus product line and blended wing body profile



Besides a number of aircraft configurations being investigated by both large aircraft manufacturers to comply with the strict requirements, the Blended Wing Body (BWB) is closest to realization with a reasonable chance to enter the market by 2030, being discussed by both large aircraft manufacturers. As a compromise between the aerodynamically high performing flying wing and the evolutionary optimized conventional airplane it offers significant advantages for operators, which is especially true for larger sized aircraft.

As the foreseeable entry into service of this type of aircraft is some time into the future, derivation and assessment of requirements reflecting market demands is difficult. This is explicitly the fact for the cabin of the aircraft, as it embodies the direct interface between the operator, customer and manufacturer in a competition driven environment. The importance of an early view of different cabin development paths by derivation of basic cabin requirements in the young stages of BWB development can be underlined with the broad variety of different BWB aircraft designs currently developed at aircraft manufacturers, scientific institutes and universities.

However, to maintain a competitive advantage it is vital for new aircraft characterized by a long life and product cycle to be as attractive as possible over a maximum period of time. Therefore, the identification of robust cabin requirements becomes eminently essential as it determines the main portion of cabin development at the start of the aircraft program and will have major influence on the potential to adapt to modified customer requirements later on in the product life cycle.

APPROACH AND AIM

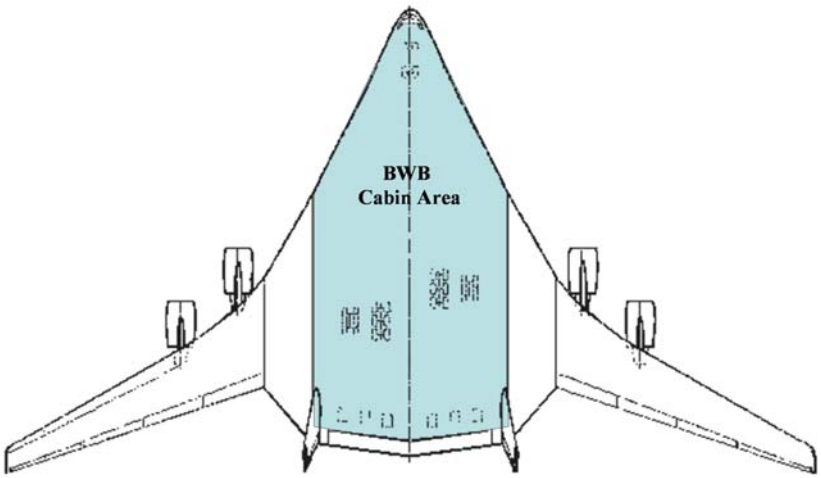
The large number of unpredictable factors from various environments—such as socio-economic; air transport and operation related; and political or technological area—has a great impact, with considerable uncertainty, on the design process. The geometric spacious room inside the BWB fuselage with unknown varieties for new cabin solutions describes a completely different type of product, for which a classical design approach is not convenient anymore. This leaves even more uncertainties for the derivation of BWB cabin requirements. Therefore, scenario techniques, as described by Strohmayer and Schmitt (2000), are applied to work out a qualitative set of comprehensive future product environments which drive the development of the BWB cabin.

The aim of the process has been to derive hard figures for key cabin parameters like seat pitch or number of galleys on the one hand and soft qualities regarding incorporated technology and process profiles on the other. With this approach, the aircraft manufacturer is capable of evaluating basic cabin design variants and options to be prepared for different customer requirements and challenges coming from the operator. This is vital from a technological as well as a marketing point of view. As a consequence, there are no restrictions regarding structural layout of the BWB, for example by concepts of single or double shell or load supporting elements for the inner structure.

The BWB aircraft is an Airbus designed configuration with the performance displayed in figure 1 (ICAS Congress, 2000). The usable cabin area is geometrically given and constant for all scenarios (no scaling). Figure

2 shows the significant difference in cabin area compared to the common cylindrical fuselage of conventional tail-aft configurations.

Figure 2. Blended wing body configuration of very efficient larger aircraft



DEVELOPED SCENARIOS

The analysis comprises the development of three different scenarios to cover a relevant range of potential evolutions. The following general assumptions are used as a basis for all of the scenarios since they characterize the development of the air transport system until 2030 and justifies the introduction of BWBs (Strohmayer & Becker, 2001):

1. Global economic growth of over 3% per year on average;
2. Global strong growth of air traffic volume of at least 4.7% per year on average;
3. Share of hub and spoke connections increases;
4. Long haul routes are predominantly served by very large aircraft;
5. Long routes are basically operated by full service carriers.

Parallel to these market conditions, the following factors have also been considered throughout the entire process;

1. Importance of flight time increases;
2. Information technology continues to propagate globally into society;
3. Anthropometric dimensions of human beings are larger;
4. Cabin safety improves; and
5. Medical care in aircraft evolves further.

The relevant scenarios, all of which have been treated equally, are presented hereunder.

"Chief Pax" Scenario

This positive reference scenario describes an optimistic environment in which political and socio-cultural stability ensures steady economic growth with a steadily increasing standard of living. Further cornerstones of this scenario are as follows:

1. Growing wealth in most of the global regions create passengers with high demands for comfort and service. This is addressed by airlines with an enhanced supply of in-flight values, covered by higher air fares. However, the relative value per price increases, resulting in profit margins comparable to current values.
2. The variety of different nationalities traveling the air and the distinctive individuality of the passenger as a result of higher living standards turns religious and cultural issues into key factors.
3. Conventional aircraft classes are refined into more and smaller user groups to react to individual needs. Passenger convenience is realized by both personal assistance by the crew and onboard systems.
4. Extensive advances in innovative technologies and processes permit a high constructional flexibility to facilitate quick and efficient changes in cabin layouts.
5. Growing restrictions from environmental issues and certification are addressed by new technologies.
6. Awareness of health issues related to air travel (e.g. the growing incident of deep vein thrombosis) increases.
7. BWB airplanes meet the expectations of airlines and passengers leading to more favorable perception of the aircraft by the public.

"Slow Motions" Scenario

As a projection of today's trend to rationalize, this scenario of slow development shows little motivation for leap innovations, and is founded in deeper society problems which affect airline strategies, as well.

1. Despite economic growth, society is split into a small wealthy group and a large population stratum with a stagnating standard of living. The gap between the lower/middle and upper class widens which leads to social inequities and is especially a phenomenon of the economic triad (USA, Europe, Japan).

2. Due to strong competition, airlines continue to be under pressure to operate with low fares and high productivity, leaving small profit margins per seat sold. Passengers have not been able to organize themselves into a powerful entity expressing their needs towards the airlines, while dragging certification processes hinder operators to introduce new standards. The evolution is inert and moving slowly, resulting in conventional cabin designs with few classes.
3. The widespread application of information technology has overtaken many procedures in daily life, leaving many people, especially older, overstrained. The development into a two-class society results in a general decline of educational and intellectual standards. Still attracted by low ticket prices, this produces a significantly higher number of passengers requiring support and assistance. The demand for help services grows because of a lack of understanding of onboard processes and technologies by many groups of the flying society.
4. The BWB convinces airlines but only receives moderate acceptance from the passenger.

"Flying Heavenly Peace Square" Scenario

The metaphoric title aims at a specific Asian market development ascending up to 2030 which is taken as a major force for this scenario.

1. Economic growth pushes the Asian countries to a similar living standard as in the western world, leading to a long-running boom in air traffic both in and with this region.
2. A steady technological evolution leads to high standards and is the basis for sophisticated technological solutions.
3. Airlines face declining profit margins with a higher demand for in-flight conveniences and can only react with highly operationally efficient cabin layouts and concepts. The need for a single class layout is one of the measures taken, evolving from a gradual transition in the Asian market towards fewer classes, which started with the advent of high passenger volumes on shorter hub routes aimed to achieve throughput and efficiency.
4. To minimize operational cost, extensive aircraft cabin reconfigurations during down-time periods or even turn-arounds (e.g. changes of passenger classes, reallocation of cabin elements, interior modifications) are not wanted by operators.

5. To attract passengers, cabin design, functionality and quality is emphasized—along with the impression of the cabin's appearance—as a premium product. Because of substantial differences in culture, it is a priority to address special considerations to the development of an adequate traveling environment.
6. Ticket price mix and marketing options for airlines are realized by seat-individual service concepts sold at travel agents, airlines or operators, in which both the technological facility standard and the in-flight comfort service can be booked.
7. The awareness for health issues on long range flights increases throughout society.

BWB CABIN STANDARDS

The derivation of key requirements for cabin development from the specific scenarios follows the methodology as described in figure 3.

Taking cabin standards of the A380 as a reference, standards for the BWB cabin are tailored according to the requirements of the specific scenario. The main geometric standards are class ratios, seat pitch, seat width, aisle width, toilets/passengers, trolleys/passengers and stowage spaces. These are influenced by both the specific characteristics of the different scenarios and the general premises of all the scenarios. These latter are the continuous growth of the average dimensions of a human being (known as acceleration; Bauch, Schmitt, and Kasch, 2001); and the need for enhanced in-flight safety and medical facilities. Acceleration, for instance, is causing an increase in body height of about 1.5 centimeters over the next 30 years, justifying a seat pitch gain of one inch, as the operational life of an aircraft is 30 years. Accordingly, the need for an additional one inch in pitch results in a reduction of at least one row in the given BWB aircraft, and has a direct impact on capacity and productivity, especially because of the shape of the cabin area.

For every scenario a set of basic technologies is identified to establish a general level from which the different scenario implications develop. The common ones are summarized in the following list:

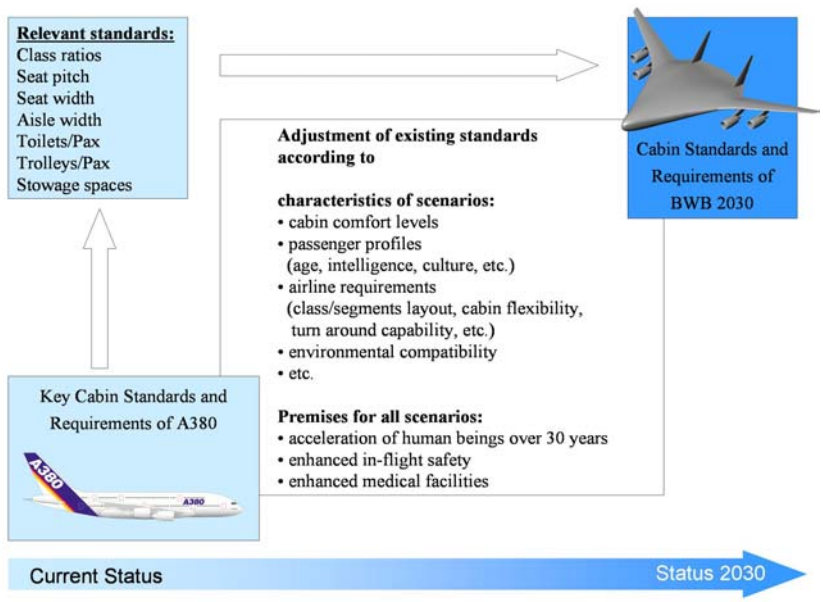
1. Communication with broad band internet;
2. Wireless blue tooth-like support of mobile equipment (phones, laptops, pagers, etc.);
3. Online information systems (passengers, cabin systems, stock data) for the crew; and
4. Intelligent boarding/deboarding systems optimizing on-board processes.

Generation of two-dimensional layouts

With these scenario-specific new standards, the number of seats in the BWB cabin is calculated. The procedure is shown in Figure 4. First, the seat areas within the BWB cabin are determined according to the given ratio of the absolute seat area and total cabin area of current aircraft (Figure 5), which is typically up to 55%. Second—with the given fuselage and unaffected by the need to scale the aircraft for a dedicated number of passengers—aisles, galleys and other remaining surface areas are determined according to the scenario needs. Also door positions, sizes and emergency evacuation paths are planned as part of the total cabin concept.

Along with consequent and logical rationales, the following scenario-specific standards for different cabin and operational concepts have been developed.

Figure 3: Derivation of blended wing body cabin standards



"Chief Pax" Scenario

The standard cabin dimensions developed for this scenario are noted in Table 1. The high standard of living and individuality combined with powerful communities of interest in this scenario enforces the influence of passengers as a prime stakeholder in the airline business. Airlines have to

react to this demand with a personalized offer to defined passenger groups like families, older people, youths or different business passenger clienteles. This is reflected by airlines with the creation of additional segments within the classical classes, especially in the economy class. As can be seen in Table 1, the class layout has been adjusted to meet different demands, which are related to ticket price and offered service. The two-dimensional layout with emergency exits can be seen in Figure 6.

Figure 4: Generation of two-dimensional layouts

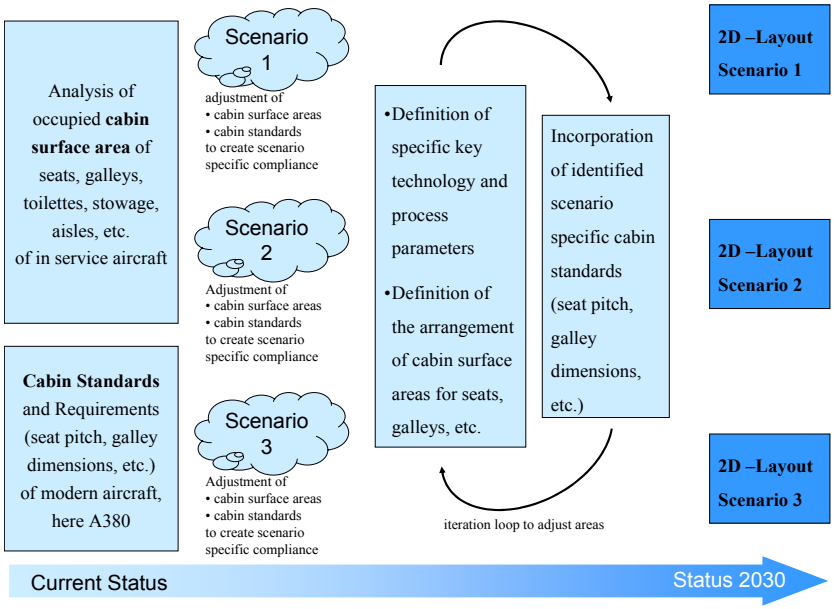
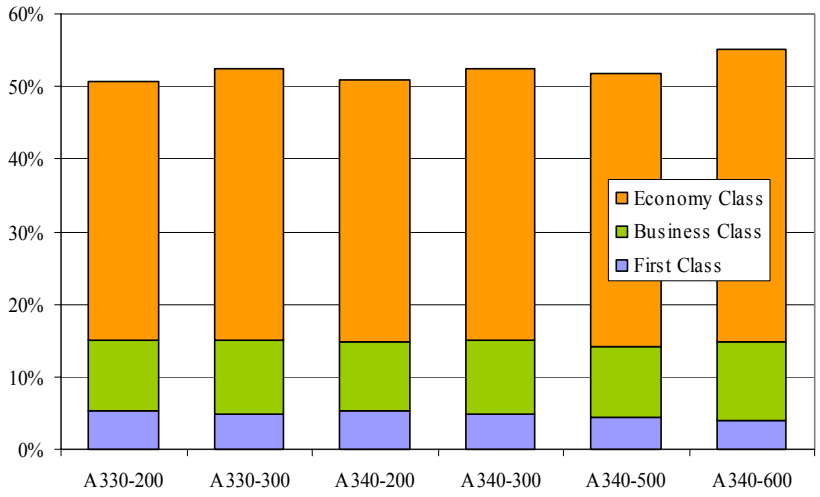


Table 1. Two-dimensional layout dimensions for the Chief Pax scenario

Cabin BWB 2030	Standard 2000 (A380)			Standard 2030 (BWB)				
	FC	BC	EC	FC	BC	EC1	EC2	EC3
Class ratios in %	4	16	80	5	12	83		
Seat pitch	62“	40“	32“	64“	42“	35“		
Seat width	30“	27,5“	25“	32“	30“	27“		
Aisle width	min 500 mm			min 570 mm				
Toilets / Pax	1 / 10	1 / 25	1 / 45	1 / 10	1 / 21	1 / 30		
Trolleys / Pax (*	1 / 2	1 / 4	1 / 10	1 / 2	1 / 4	1 / 10		
- Stowage space / Pax	25“x2“	25“x1,5“	1 Tray	25“x2“	25“x1,5“	25“x1“	1 Tray	1 Tray
- Hand luggage	2	2	1	3	2	1		

Figure 5. Absolute seat area as a portion of total cabin area



With aisle widths orientating at conventional dimensions, the cabin layout has to be designed attractively to achieve a favorable perception from the passenger. An unconventional approach of a bended main broad aisle (2 meters) assures quick boarding and deboarding in the critical entrance areas. The familiar approach of a cabin divided into classes, with first class in the front, is maintained. High service levels are addressed with additional facilities in the lower deck compartments with crew rest rooms, fitness and children areas and a social meeting point (with bar). Assistance for the passenger is obtained in the front and the middle information desk to explore the full range of service supply during flight (indicated by "i" on Figure 6). Two additional service points (indicated by "s" on Figure 6) in the economy classes underline the higher-quality traveling level.

Emergency exits are provided all around the cabin area with wing and aft exits according to FAR 25.807 of type B dimensions (75 passengers per minute), two type A doors per side in the front (110 passengers per minute) and the main entrance with a new standard type 0 door (double Type A with 200 passengers per minute). The design ends up with 730 passengers in a standard layout. Some artist impressions of the cabin are elaborated in figures 7 and 8.

Figure 6. Two-dimensional layout with emergency exits, Chief Pax scenario with 730 passengers

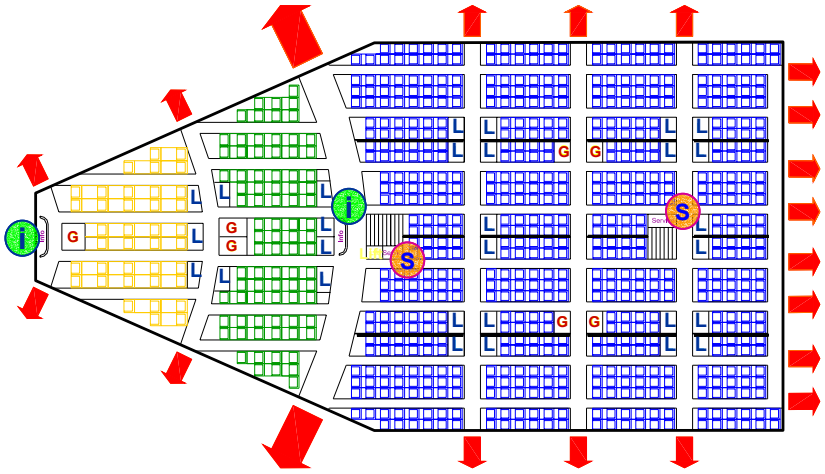


Figure 7. Three-dimensional impression of main aisle, Chief Pax scenario

Figure 8. Three-dimensional impression of lower deck facilities, Chief Pax scenario

"Slow Motions" Scenario

The standard cabin dimensions developed for this scenario are noted in Table 2. The scenario is based on a two class society and, thus, has two levels of treatment of passengers during flight (Figure 9). With declining profit margins, the inert evolution of innovative cabin ideas together with the low paying traveler leads to a conventional standard class system. The lack of airline demand for conversion of cabin elements in or during aircraft operation entail limited flexibility for cabin elements. Major cabin reconfigurations can only be realized at C or larger maintenance checks during aircraft overhaul. The scenario is characterized by the strong differentiation between standards of high revenue (first and business) class and low revenue (economy) class, which is, for example, obvious with the number of galleys and toilets per passenger. Service as well as supplied technology levels is significantly down-graded in economy class, focusing on efficiency and productivity for the airline. However, the larger share of older, immobile (wheelchairs) and larger passengers demands larger aisles. The service concept ensures convenient and quick operation through an automatic trolley distribution system with elevators which are integrated in

the emergency stairs leading to the roof. The highly cost-efficient systems for simple operation limit the comfort of the passenger. On the other hand, first and business class have an optimized traveling environment and high-end service standards. Sophisticated comfort levels with on-seat climate, individual ergonomic adjustable seats, sound and light surround the high yield passengers that generate the major part of the airlines' revenues.

Table 2. Two-dimensional layout dimensions for the Slow Motions scenario

Cabin BWB 2030	Standard 2000 (A380)			Standard 2030 (BWB)		
	FC	BC	EC	FC	BC	EC
Class ratios in %	4	16	80	4	16	80
Seat pitch	62"	40"	32"	65"	42"	33"
Seat width	30"	27,5"	25"	32"	29"	26"
Aisle width	min 500 mm			1m	0,95m	0,9 / 0,6m
Toilets / Pax	1 / 10	1 / 25	1 / 45	1 / 10	1 / 25	1 / 45
Trolleys / Pax (*	1 / 2	1 / 4	1 / 10	1 / 2	1 / 4	1 / 10
- Stowage space / Pax	25"x2"	25"x1,5"	1 Tray	25"x2"	25"x1,5"	1 Tray
- Hand luggage	2	2	1	3	2	1

The location of crew rest compartments as well as the accommodation of trolleys in galleys at the lower deck realizes more productive seat area on the main deck. The design ends up with 808 passengers in a standard layout. Some views of the cabin are sketched in figures 10 and 11.

Figure 9. Two-dimensional layout with emergency exits, Slow Motions scenario with 808 passengers

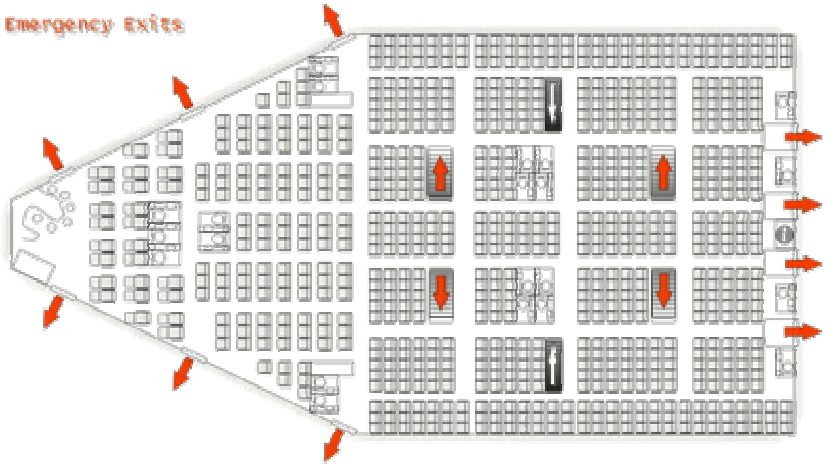


Figure 10. Three-dimensional sketch of emergency stairs, Slow Motions scenario

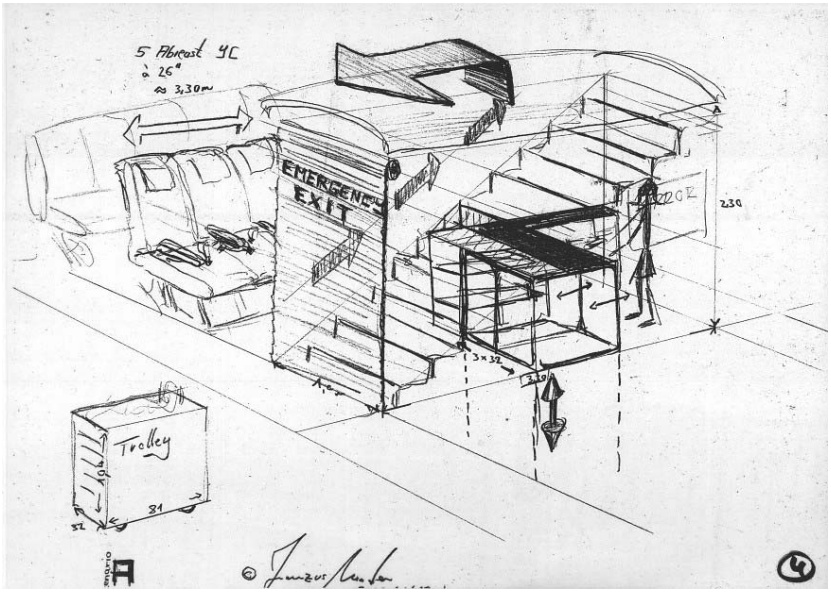
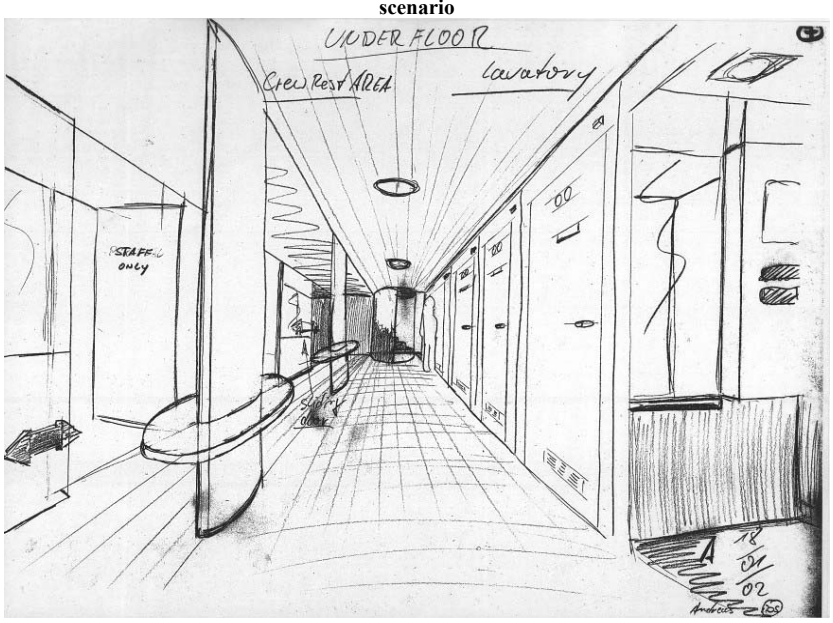


Figure 11. Three-dimensional sketch of lower deck crew rest and lavatory, Slow Motions scenario



"Flying Heavenly Peace Square" Scenario

The standard cabin dimensions developed for this scenario are noted in Table 3. The proposed single class layout has been worked out along with the demand for high profitability (Figure 12). Two versions are presented by the manufacturer to the airline: (a) a standard configuration with a larger seat pitch of 36 inches and 768 passengers and (b) a high density configuration with a reduced 34 inches pitch and 871 passengers to comply with the greater traffic volume on inner Asian routes. As the technologically most innovative scenario, a passenger container system is developed to achieve short turn-arounds (higher frequency) and high operational efficiency. The dashed line shows the outline of a container, which is boarded in the airport area, transported to the aircraft and loaded into it from the tail. The inner service area with galleys and toilets are built-in elements with a high degree of automation. Intelligent robot trolleys assist the crew with cabin operations, for instance, and take over major parts of the food and beverage service. More toilets, vending machines and trolley transport systems are installed in the lower deck. A highly sophisticated virtual reality environment with 3D-glasses and head sets is adjusting to the demands of the individual passenger and succeeds to shorten the subjective flight time.

In case of emergency, in contradiction to current certification rules, wing emergency exits are blasted away after intelligent hazard detection systems decide the safest way of evacuation. If necessary and possible, the big tail doors are opened to quickly evacuate the plane. Some views of the cabin are sketched in figures 13 and 14.

Table 3. Two-dimensional layout dimensions for the Flying Heavenly Peace Square scenario

Cabin BWB 2030	Standard 2000 (A380)			Standard 2030 (BWB)	
	FC	BC	EC	Standard config.	High density config.
Class ratios in %	4	16	80	100	100
Seat pitch	62"	40"	32"	36"	34"
Seat width	30"	27,5"	25"	27"	27"
Aisle width	min 500 mm			1,0 / 0,6m	
Toilets / Pax	1 / 10	1 / 25	1 / 45	1 / 32	1 / 42
Trolleys / Pax (*	1 / 2	1 / 4	1 / 10	1 / 6	1 / 8
- Stowage space / Pax	25"x2"	25"x1,5"	1 Tray	1 Tray	1 Tray
- Hand luggage	2	2	1	2	2

(* Trolleys for 40 / 60 / 80 tablets; dimensions standard trolley: width: 12" / depth: 32" / height: 41")

Figure 12. Two-dimensional layout with emergency exits, Flying Heavenly Peace Square scenario in standard layout with 768 passengers

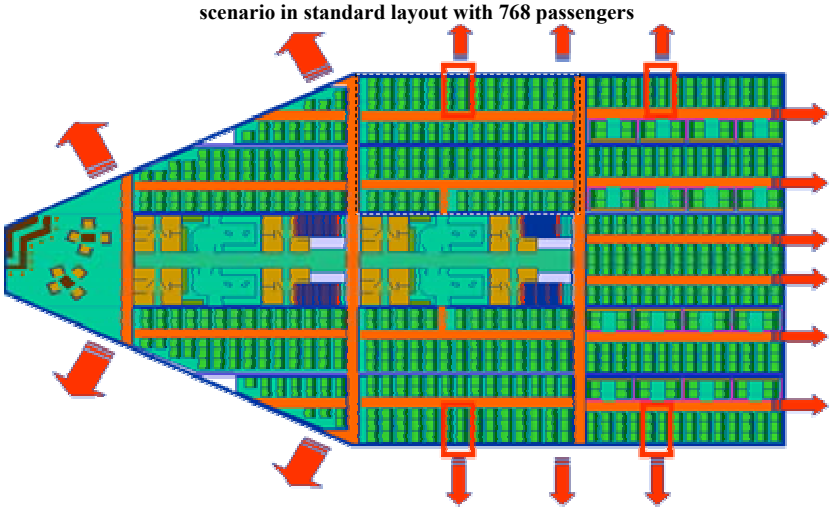


Figure 13. Three-dimensional sketch of tail container loading, Flying Heavenly Peace Square scenario

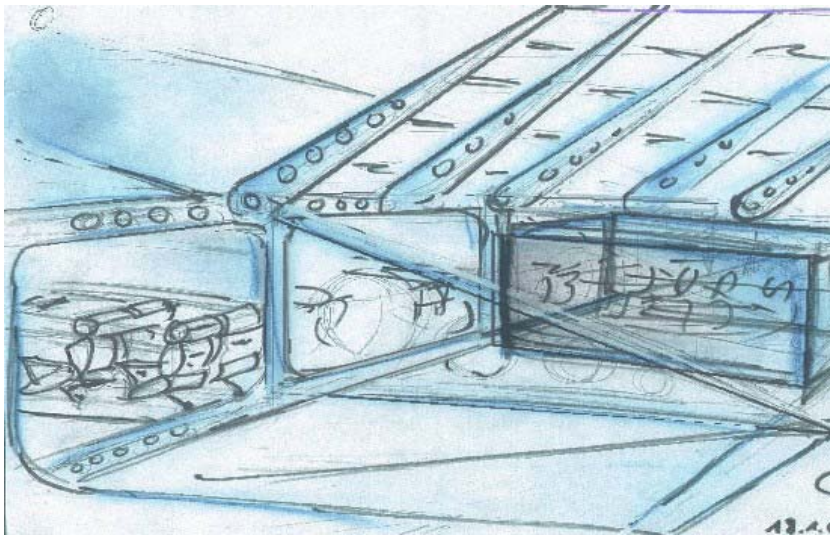
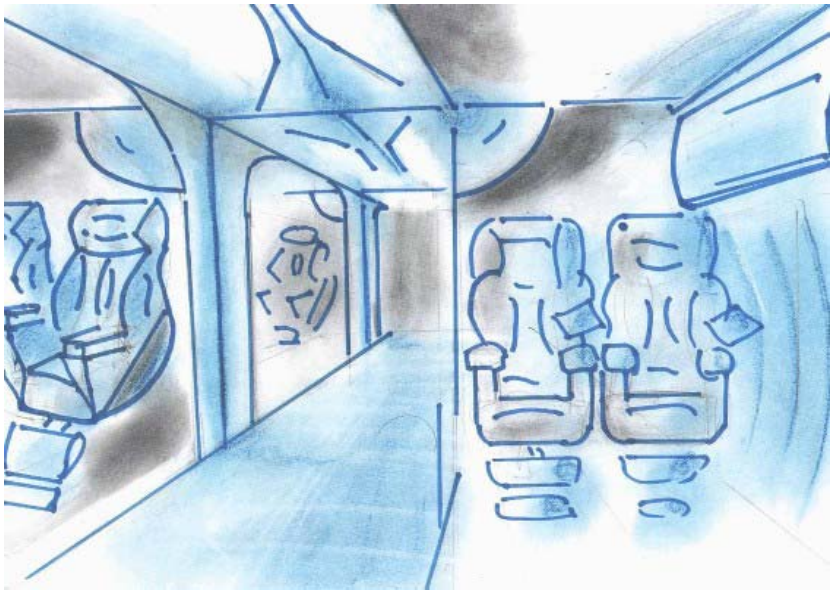


Figure 14. Three-dimensional sketch of container interior design, Flying Heavenly Peace Square scenario



Evaluation of requirements

The different scenarios developed a range of scenario-specific requirements of the cabin layout and development as well as primary cabin systems. To evaluate the robustness of these requirements, they have been introduced into all three scenarios and assessed for their fit with the particular scenario. The main results of this comparison are listed below:

1. Increase in seat pitch despite the fact that adjustments are a matter of airlines;
2. Standardization of broader aisles (defining cabin layouts significantly!);
3. Development of enhanced boarding and seat allocation systems with intelligent passenger flow control;
4. Utilization of the lower deck area: a major factor dependent on how strict regulations are towards passengers in the future;
5. Availability of wireless communication technologies inside the cabin (passenger on-board system);
6. Lobbying for enhanced certification rules;
7. Alternative and decentralized on-board high power generation (e.g. fuel cells) for a more electrical aircraft configuration

(substitution of pneumatic and hydraulic systems by electric ones, e.g. electric air conditioning, requiring high electric power)

8. Use of easy-to-clean materials (similar to lotus flower effect);
9. Recycling of operating supply items (water, oil, etc.);
10. Availability of computer-aided direct view video system (passenger control during take-off and landing, monitor surveillance by crew);
11. Intuitive emergency procedures; and
12. Intelligent escape slides.

CONCLUSIONS

With the help of scenario methodologies a consistent and structured approach towards the derivation of cabin requirements were found, adopted and validated through three scenario-specific and independent cabin concepts. Economic, socio-cultural and technologic objectives were considered throughout the process, leading to different cabin layouts and models driving future designs. In a final step, robust requirements were formulated by qualitatively evaluating the scenario evolved from the respective future environments. With the proposed methodology, strategic recommendations for the aircraft manufacturer are presented which can be adopted for other BWB configurations as well.

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FUTURE SCENARIOS FOR THE EUROPEAN AIRLINE INDUSTRY: A MARKETING-BASED PERSPECTIVE

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ABSTRACT

The last couple of years have proven to be very tough for the airline industry. Macroeconomic turmoil, like 9/11, consequent economic recession, the threat of terrorism and the SARS virus have all had a combined drastic effect on both volumes and values of traffic performed by the industry. Microeconomic and industry-related changes, most definitively the dramatic growth of market power of low-cost carriers (LCCs), are haloing this condition of the airline environment, putting into deep crisis incumbents' traditional business models and giving life to liquidity losses, huge deficits and bankrupts. In the U.S. market, LCCs have been a reality since the early 1970s and have been counterattacked many times, with scarce luck, by incumbent network carriers. In the European environment, instead, LCCs' attack is fresher and the ultimate answers by national carriers are still to be put into practice. The risks of inaction, however, are probably stronger than in the U.S., due to the higher fragmentation of the European industry and the States' ownership of many carriers that still prevent radically invasive market reactions like mergers. After an introductory but compulsory parenthesis on the rise of the low-cost phenomenon in the airline industry, this paper aims to analyze the new market scenario for the airline industry, focusing on the European context. Furthermore, the paper will analyze the main marketing tactics UE carriers might adopt to cope with the huge wave of low-cost entities and survive in the current tough environment.

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CHANGING THE RULES OF THE GAME: THE NEW HYPERCOMPETATIVE CONTEST FOR AIRLINES AND THE RISE OF LOW-COST CARRIERS

Since the 1970s, traditional market leaders in industry after industry, saddled with complex, high-cost business models, have been under attack by companies with new, simpler ways to manage their operations and contain costs. This scenario occurred in the steel industry, when minimills took on traditional smelters; in automobile manufacturing, when more standardized Japanese cars won out over customized U.S. vehicles; in retailing, when superstores overtook conventional grocery stores (Hansson, Ringbeck & Franke, 2002); and, eventually, in fixed telecommunications. The concept of value migration best describes the flow of profit and shareholders' wealth across the business chessboard. Value leaves economically obsolete designs and flows to reinforce new business designs, that are capable of creating equal, if not an increasing, utility for the customer and capture value for the producer. This situation also explains why firms with similar product or service offerings, as it is in the broad environment of commodities, can produce significantly variant economic performances (Slywotzky, 1995).

In the case of airlines, the demise of tight regulation and the consequent rise of hyper competition have brought an abrupt end to the age of chivalry for this mature industry. In other words, within a short amount of time, historical rather than forced cooperation and chivalry have been cancelled as business pillars. The erosion of monopolies and oligopolies by means of new start-up value propositions, first in the U.S. and later in Europe, has dramatically changed the codes of competitive conduct and radically altered the customer's perception of the airline service, too. In other words, the gentility of tacit collusion and avoiding head-on competition, which were typically working in the regulated era, are now gone (D'Aveni, 1995), with mature airline service rapidly moving from value-added experience to pure commodity. This shift in the definition of competition has been relatively rapid and was largely unexpected even to the deregulation's advocates.

Waves of new carriers jumped, and later abandoned, notwithstanding the political exit barriers that the industry faces, deregulated environments. In the U.S, first, and later on all around the globe, a new category killer entered the market scene. Low-Cost Carriers (LCCs) provided a new, simplified value proposition to a wider market potential and rapidly acquired huge numbers of customers. The challenge, from that time on, has been for traditional carriers to cope with this apparently perfect and superior economic travel formula.

TRADITIONAL AIRLINES VERSUS LOW-COST CARRIERS

In fact, what has been a tough challenge since the early beginnings for network-based, traditional operators in the fight with LCCs is basically the confrontation between two radically different business models. The formers' one is based on a calm, oligopolistic market aimed to support the idea of global coverage of the entire world arena. The latters' one, instead, is apparently only focused on a more niche oriented approach. In fact, it is aimed at getting benefit from offer vacuums and from the service of *pariah customers*, starting from visiting friends and relatives, ethnic and leisure based movements and later on climbing up to reach cost-conscious business travelers. Tables 1 and 2 summarize the main differences in the market approaches of network-based and low-cost carriers.

In fact, some of the basic advantages of LCCs are apparently quite obvious and are certainly not industry-specific. For instance, part of a better cost management process can be easily correlated to the fresh market entry and, thus, to highly efficient hiring and salary practices for both headquarter staffs and crews. Another benefit, most definitively in the European context, may be linked to some form of comparative advantages, like in the case of a more favourable fiscal legislation providing tax incentives for local operators. For instance, Ryanair is registered in Ireland, where corporate taxes are far lower than in other countries of the continent, like Belgium. Eventually, effective business-to-business (B2B) tariff negotiations that many LCCs are able to perform[1] are simply a consequence of airports' vulnerability, due to the absence of a clear airport marketing activity[2] (Jarach, 2002). In fact, in every industry facing power imbalances in pipeline relationships, opportunistic behaviours by channel leaders are in practice to exploit the power imbalance of the counterpart, typically in the form of huge discounts (Jarach, 2001).

This said, evidence shows that some parts of LCCs' healthy cost condition could also be apparently matched by traditional carriers through isolated[3] copying of some of the LCCs' business elements. For instance, a narrower cost imbalance could also be obtained by sporadic rather than cosmetic measures, like firing personnel and then hiring personnel back at lower salaries, as the Swissair-Swiss conduct explains. Or through the

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[1] Frequently in the form of huge subsidies for start-up and expansion of low-cost operations.

[2] This means the absence of a clear airport market positioning and, consequently, no airport marketing plan.

[3] This means that these measures are not coordinated and integrated inside a strategic business plan or reengineering platform.

creation of an subsidiary that is being responsible for all aircraft purchases and leasing transactions, for instance. Most of the other elements of the LCCs' formula, however, seem to request a much more radically deeper reengineering of the entire value proposition and are not definitively sensitive only to one shot actions.

Table 1. The pillars of network-based airlines

⇨	Massive marketing expenses (advertising, Frequent Flier Programs, travel agents' overrides, network analysis)
⇨	Expensive fragmented and complex services (classes of tariffs and service, catering, lounges, ground services, etc.)
⇨	Massive use of technology (hard technology: aircraft tailored for each route and prescription; soft technology: CRS legacy systems)
⇨	Ancient-regime financial targets (in contrast with macroeconomic shockwaves and lifestyle changes)

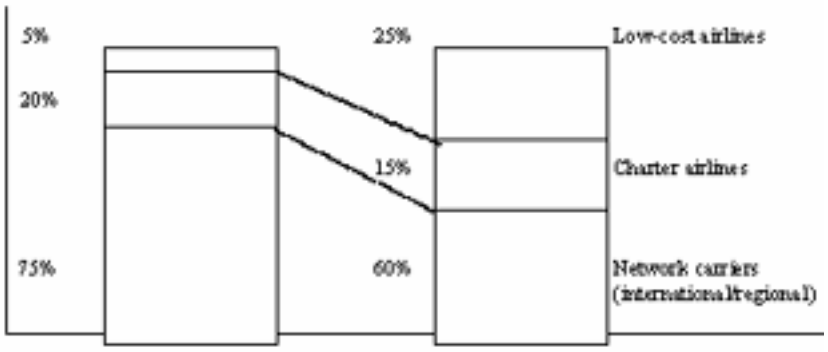
Table 2. The pillars of low-cost airlines

⇨	Minimal marketing expenses (word-of-mouth on comparative advertising, airports' supports)
⇨	Personal, convenient and pleasant service (reengineering around core benefits, easy price discrimination)
⇨	Judicious use of technology (hard technology: fleet standardization; soft technology: Internet and CRS avoidance)
⇨	Structural efficiencies (no overstaffing, high productivity, no hubbing costs
⇨	Realistic financial targets (based on their own business model)

The fact is that you do not need to be a start-up to build a business model focused on a previously ignored market, but it helps. Established companies have great difficulty seeing how unprofitable segments can be served profitably, particularly if those established companies have been very successful. That is because their own success blinds them to opportunities right in front of them, in a sort of business myopia. For example, try to put

yourself in the shoes of the executives who ran the dominant airline of the 1970s and 1980s and watched a struggling Southwest Airlines try to get off the ground. With the failures of discount carriers People Express and Laker Airways making headlines, would you have believed that another cut-rate U.S. airline would survive, much less become the most profitable carrier (Rosemblum, Tomlison, & Scott, 2003).

Figure 1. Projected change in intra-European passenger market shares, 2000-2010



Source: Association of European Airlines and International Air Transport Association, internal figures, 2000

THE CHALLENGE OF OUR TIMES

Coming to the current situation, the world's major traditional carriers are being faced with some of the worst—rather than hardest and unpredictable—challenges in the rules of the game of their market environment since the first Wright Brothers' flight at Kitty Hawk just 100 years ago. For instance, U.S carriers alone lost more than $10 billion in 2002, according to the Air Transport Association, up from the $8 billion in the disastrous year of 2001 and, generally speaking, worldwide airline losses topped $50 billion in 2002 (Hansson, Ringbeck & Franke, 2002). These tragic figures necessarily ask for a deep analysis and request to understand all the real causes, distinguishing the cyclically-correlated ones from the structural ones.

The traditional carriers' business model has been a great success and a major innovation when looking back at the early 1990s, but today it is showing to be unsustainable in the current form. Strictly tied to massive physical infrastructures, diverse and inconsistent fleets of aircraft, legacy information systems and large labor pools, traditional airlines are today struggling to give even a medium-term perspective to their existence on the market. Most definitively, what seems today highly debilitating for

traditional carriers is their inability to overcome their cost burdens with boom period pricing, as they did in the second half of the 1990s. From one side, post-9/11 economic de-facto[4] recession and the inherent constant terrorist threat, with the adding of the second Gulf War, are still keeping away vast amounts of passengers from worldwide carriers. From the other side, the recent SARS world health alarm and the consequent travel warnings and bans by the World Health Organization for China, Hong Kong, Singapore and Taiwan has simply cancelled for a number of months the Far East arena as an air travel destination for both business and leisure traffics, with major airlines implementing up to 90% capacity cuts on the previous flown hours to the area. As a parallel consequence, these macroeconomic events are accelerating the pace of diffusion of videoconferences as an adequate substitute for meetings. This is another clear signal that these external shocks will not be absorbed by carriers with the same substantial inaction performed during the previous cyclical crisis.

On a microeconomic, industry-related focus, instead, this tough airline environment is proving to be apparently much healthier for LCCs that are dramatically increasing their own market shares on a worldwide basis. What can be highly surprising for non-industry analysts finds, instead, rather simple, non-technical explanations. For instance, sales figures[5] prove that SARS and the threat of terrorism are still preventing long-haul travels, most definitively in the case of highly-sensitive, risky destinations, like China, Canada or the Middle-East. On the contrary, this negative effect is much less in the case of short-haul flights[6], where safer trips are involved and where tariff stimulation[7] may push tourists and business professionals to abandon personal or company flight bans.

The impact of both these macro and microeconomic turmoils on technical indexes for International Air Transport Association (IATA) actors has been quite immediate. Traditional carriers are being faced with a significant yield dilution with a steeper-than-forecasted curve, well over the 2-3% decline recorded on a year-round base in the last decade. This condition finds quantitative evidence to the fact that cost per average seat mile (CASM) runs well over revenue per average seat mile (RASM), this gap already reached 2 cents per seat mile at the beginning of 2002 in the U.S

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[4] Generally speaking, economic macroindicators do not reflect on a worldwide basis a situation of recession. However, it is vastly accepted that terrorist attacks create uncertainty conditions for the market, and this blocks long-term investments.

[5] Provided by IATA and American Express, for instance.

[6] These sales figures do not include the two weeks immediately following 9/11.

[7] This situation can be easily explained by the negative demand-to-price elasticity that is now starting to affect even business travel, where budget cuts reduce travel or shifts it to LCCs.

(Hansson, Ringbeck & Franke, 2002). In a condition of fixed-costs that reach up to 90% of total costs and with few chances of cutting them in the short period, this revenue-cost imbalance naturally gives life to huge deficits, liquidity crises, job cuts, network reductions and, eventually, bankruptcies. This was the case in North America for Chapter 11 filings of USAirways, United Airlines, Hawaiian Airlines and Air Canada. Or in Europe for the bankruptcy of Swissair and Sabena, where these companies failed and entered the arena again with a different brand, but taking on the same historical and structural weaknesses, in what could be described as a sort of European answer to the U.S Chapter 11 instrument.

Thus, in order to survive, major airlines have no choice but to change their course, modifying their rigid business model to better match the challenge by LCCs. Although making fundamental changes in a long-standing business model is difficult and risky, it is not without precedents; it has happened in the manufacturing and financial services contexts. And, by far, the risk of inaction is much greater than the risk to change and the difficulty of finding a new working business path.

THE EUROPEAN BUSINESS CASE

In the EU environment, the late 1980s' airline deregulation process has pushed in dozens of start-up entries and, consequently, fierce price competition on many route legs. This condition has progressively pushed many former flag carriers into deep competitive and financial crises, as their cost structures were based on the previous oligopolistic regime and, thus, not consistent with new hypercompetitive patterns of action.

A major difference with the U.S. environment, however, lies in the fact that Europe has not recorded any significant capacity exit from the industry, as the above described Swissair-Sabena cases clearly evidence. On the contrary, recent announcements once again demonstrate that the *one country, one flag carrier* model is still working, but no longer achievable, especially in the case of small countries with a limited origin/destination demand[8]. If we exclude some small regional airlines and the notable exceptions of Ryanair-Buzz and Easyjet-Go in the low-cost cluster, no consolidation practices have taken place,. According to pure economic figures, no more than 4 national carriers and 20 regional carriers should act in the EU environment. Notwithstanding this, we still have 20 medium-sized airlines

[8] Swiss, the Switzerland's national carrier, is probably the best example. But the same condition can be applied also in the case of Holland, Austria, Portugal and Greece, for instance, where global ambitions of local carriers have necessarily lowered the state-of-the-art market conditions.

and more than 50 regional airlines working, a figure that is continually increasing.

This high level of fragmentation, which many times has only an apparent basis in air service agreements' (ASA) ownership clauses, is reflected in the relatively low market force each major can deploy in the confrontation with large U.S. trunks and, definitively, with LCCs. While alliances have been a good solution for entering close markets or partly increasing revenues, they have actually failed in the goal of reaching higher cost efficiency. In this sense, we can say that until now partnerships have only marginally impacted on the chronic economic and cost vulnerabilities of EU carriers.

These elements help to explain why LCCs have really boomed for the last couple of years in the continental context. Recent post-9/11 updated statistics reveal that European LCCs are expected to account for up to 25% of the market by 2010, following the same path of market expansion that is taking place in the U.S., where some analysts predict that LCCs could reach up to 70% of domestic services. Figure 1 shows the current and the expected market condition in the European airline industry.

Today, Ryanair, Easyjet, Germanwings, Hapag Llyod Express and other European low-cost entities are abandoning their traditional British focus to explore other huge continental catchment areas in Germany, France and Italy. Acting as flexible, dynamic and innovative players, they are eroding the advantages of network airlines and making healthy profits. Or, when not yet profitable, they are consolidating market shares to build a greater critical mass or slot dominance on key airports[9].

The real strategic ultimate issue for European traditional carriers, however, is that they are not facing a unique and standardized low-cost business model, as a sort of European adaptation of the original no-frills American formula has taken place. Some LCCs, for instance, are considered pure Southwest clones and focus primarily on visiting friends and relatives and ethnic traffic: Ryanair is the best example. Others, like Easyjet, have since the beginning had a different focus aiming at capturing cost-conscious business travelers, and probably are the real top danger for traditional operators.

In this sense, time for change has come: major carriers have to choose between one of or a combination of six possible counter reactive market strategies to cope with LCCs. These tactics can be equally implemented in all market scenarios where traditional carriers are being touched by the low cost formula. Thus, they can equally work, if not already in place, in the

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[9] As in the Easyjet-Paris Orly tentative, or in the Ryanair-Stansted or Easyjet-Luton cases.

U.S., European or Asian environments. The pace of introduction of these market reactions, however, is much more urgent in Europe, where the threat is fresher and past conditions have created airline structures that must compulsorily be changed in the short-time. In other words, this goal has to be rapidly implemented, if the European industry aims to play a role in the world scenario in the next ten years[10].

SIX MARKET STRATEGIES FOR TRADITIONAL CARRIERS TO COUNTER REACT TO LCCs

On the basis of what has been previously said, European traditional airlines have to choose not only which part of the battlefield stay, but also which kind of market tactics to use to cope with the New Millennium challenges.

Although some academics predict that there will soon be only low-cost operators for all markets, even long-haul ones, we do not believe so. Chances for most of today's traditional carriers to survive, however, lie in a rapid adoption of one or more of the following six counter reactive tactics.

Resist

This option is the most conservative a traditional carrier may implement. The basis for this choice logically lies in the perception that LCCs are simply a fad and that, sooner or later, they will be abandoned by frustrated passengers coming back to the higher price/comfort combination. As a consequence, a traditional carrier will continue to do business as usual, eventually modifying only its own timetable with the aim of bracketing the low cost offer, for instance.

Airline managers frequently make comparisons between their own industry and what happened some years ago in the retailing arena. In that case, deep discounters were experiencing a rapid, massive growth, too. In the long-term, however, their market power was sometimes deeply marginalised In other words, airline managers believe that passengers are only migrating to LCCs out of curiosity and the low cost, but with no risks of developing loyalty to them. According to this thesis, these customers will, in fact, come back to what basically is believed to be a better overall deal

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[10] It is important to underline that LCCs are beneficial to customers, thanks to their low tariffs. But, at the same time, their pressure on traditional carriers naturally forces the latter to streamline, for instance, abandoning unprofitable routes. This means that competition between countries can be affected, too, not forgetting that carriers are the logical facilitator of globalisation and movement of goods and people.

The mistakes of this approach are clear. First, market segmentation postulates that customers are naturally different in their value perceptions and conceives that some people could easily become loyal to the no-frills formula if it fits with their perceived value[11]. Second, huge price gaps resulting from direct competition on the same routes and airports, like in the case between a traditional carrier and a hybrid LCC, will naturally support the choice to switch to the cheaper alternative. This condition will likely have a broader impact on customers' travel lifestyles and will progressively marginalise traditional carriers from the profit zone of the market. The traditional airline will then be forced to try the retrench tactic.

In this sense, the only real way to maintain the market status quo for a traditional carrier is through State supports in the form of subsidies or rigid slot allocations that prevent LCCs from entering the former's national skies. The recent slot lottery at Paris Orly after the bankruptcy of Air Lib Express is frequently mentioned by Easyjet as a clear protectionist attitude by the French authorities to Air France.

Adapt

This option is, again, one of the least invasive, both from a political and a financial point of view. It aims to reach a minor impact on flight operations, but certainly not a deep reengineering of any structural value-chain processes. In this situation, airlines will adapt their own business model to that of LCCs by means of a copying strategy, with the goal of integrating in its own business models the simplest elements of the LCCs' design. The return to point-to-point service focus[12], for instance, is applied by the traditional carrier through lowering waves-based network interrelations in the form of more viable rolling hub concepts. This option is being implemented by American Airlines and is dramatically improving the company's productivity levels, while offering at the same time a chance to better serve lucrative origin/destination traffic and abandon uneconomical connecting routes.

Moreover, a reduction of in-flight catering frills may have a positive impact not only in the form of lowering direct costs, but also permitting to leave off galleys from aircraft interiors, with a chance of improving seating figures for the aircraft. This option is being done in Europe by Lufthansa,

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[11] The perceived value is the ratio between the benefits a service and a brand can offer to customers divided by the sacrifices a customer has to make to use that service and brand as opposed to other services and brands.

[12] Historically, we can say that traditional carriers had been tightly focused on point-to-point traffic. Deregulation required the need to develop hub-and-spokes networks.

Alitalia and Swiss[13] and probably offers the most apparent cost relief to traditional carriers.

Retrench

Back in the 1980s, when facing a calmer market environment and basically a form of non-price competition, traditional carriers started to increase the scope and variety of their products by layering on new offerings to serve even larger and more diverse customer bases. This differentiation process faces a natural crisis when markets become mature and overcapacity forces to implement price cuts to retain demand. In mature markets simplicity, not complexity, seems to pay off when fighting for the supremacy of its own value proposition.

In this sense, failure in facing the LCCs' attack and scouting new inelastic clusters causes the traditional carrier to retrench. This process is being implemented by means of job cuts, network streamlining and capacity reductions. Each one of these three alternatives has clear pros, but a number of cons can equally arise.

Job-cutting measures would, for instance, dramatically benefit the profit/loss accounts of what is still a labour-intensive industry. However, the frequent risk is that, in reality, they can be implemented only after tight confrontations with unions and numerous strikes would significantly damage the carrier's image and reputation. This is why, under a purely financial metric, a long-term relevant benefit has to be actually discounted by subtracting lost sales and image and reputation damages[14]. By quantifying all these elements, some of them with clear psychological impact, it looks like job cuts have frequently proven to be only a panacea for the carrier, while not solving structural issues. A cosmetic solution to the problem of overstaffing can be achieved by firing off less unionised categories, like headquarter staffs, or by imposing cooperative salary reductions in exchange for job security. A similar experiment was conducted by Alitalia, but this option has not actually proved a good bargain for the company[15].

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[13] The three carriers are actually following different approaches on this matter. Lufthansa is cutting domestic catering to reduce the number of galleys to obtain more seating. Alitalia recently tried to cut its domestic catering with the goal of reducing the number of cabin crews, matched with the elimination of seats as to comply with International Civil Aeronautics Organization (ICAO) rules. Swiss recently decided to suspend free-of-charge catering in economy class, following a similar approach to that of LCCs.

[14] The result can be achieving by using this formula: *Long-term cost benefit = Cost saving from salaries – lost sales (t to t+1) – reputation damages (t + t+1) – loss of motivation.*

[15] Unfortunately, however, cost drivers for a carrier lie in the unionised crews, not in the back office.

Network streamlining focuses on reducing losses by cancelling unprofitable routes. Traditional carriers, when following this approach, usually decide to act first on long-haul destinations, due to the combination of high operating costs and inefficiencies in their price structures[16]. A narrower scope of action for a traditional airline, however, impacts dramatically on its own distinctive visibility, as network contraction actually reduces the hub-based, global carrier's attractiveness and seriously compromises its marketing promise of a seamless service to wherever.

Overall or route-focused capacity reduction, instead, may prove to be the best of the three alternatives. By phasing out current planes and trading them with smaller ones, airlines can better match demand in off-peak periods or on highly-contestable routes, thus applying simpler yield management practices, too. This option can be implemented statically by simply exchanging old planes with new smaller ones[17], or dynamically by combining for every route the capacity of different aircraft of the same family, as it works in the Airbus A318, A319, A320 and A321 case. This tactic would naturally drive LCCs to become volume leaders on trunk routes, with traditional carriers abandoning their anachronistic market share targets and refocusing on net present value upgrades. This approach is being implemented by British Airways, which has been hardly touched by LCCs after it lost in a couple of years some 15% of the all intra-European origin/destination traffic.

Fight

The fight option asks for the traditional carrier to go head-to-head with the LCCs by almost entirely matching its tariff policy. A vast amount of managerial literature illustrates the risks of a price war contest and how this risky decision should be undertaken only when a solid cost advantage is retained. This is definitively not the case for all traditional carriers. These elements help to understand why[18] fare wars usually take place not only in the first periods of LCCs' market entry, but also on a route-by-route basis and with the clear aim of avoiding halo consequences on the rest of the

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[16] The current pricing philosophy in the airline business asks carriers to hugely discount their own tariffs as to satisfy all clusters. On long-haul routes, hugely discounted prices are used to attract tourist traffic. These special tariffs, such as Public Excursion (PEX) or Advance Purchase Excursion (APEX) tariffs, seldom cover the per-capita cost of the flight, especially in the case of highly inefficient operators.

[17] This is currently the case of USAirways, which is phasing out F100s and some B737s and substituting them with smaller RJs from Bombardier and Embraer.

[18] Back in the 1980s, instead, tariff confrontation was performed on a national basis, as the U.S. market has shown.

traditional airline's markets[19]. However, there is also empirical evidence of a longer, more subtle, form of price war between the incumbent and the new entrant. This kind of alternative works when the traditional carrier is strongly attacked by the LCCs in the former's domestic market. In this case, the fight option is also done by means of some indirect pricing tactics. A typical example is provided by the tactic of increasing commissions paid by travel agents in order to block access to trade and increase the distortion power the agent can have on customers' purchase decisions (Jarach, 2002).

By copying the LCCs' pricing, a traditional operator basically tries to defend its volume market share and to discourage the new entrant from further invasion plans. This option seems inconsistent because traditional, high-cost carriers should target high-yield traffic while not focusing their attention on load factors only, and consequently on low-yield, ethnic traffic, for instance.

Join

The join option requests a traditional carrier to directly enter the low-cost cluster with an identical business design. This can apparently take place in two different ways.

The first one is the creation of a low cost subsidiary by traditional carriers. This alternative will prove to pay off its best results if the airline is really able to rigidly split business traffic and leisure and visiting friends and relatives movements, the former being allocated to the main trunk carrier and the latter to the low-cost subsidiary. In this case, the low-cost subsidiary becomes responsible of all highly contestable routes where price cuts can be sustained only by a similar cost structure of that of the attacking LCC.

This case was first provided by the U.S. environment in the early 1990s, with United giving life to Shuttle, USAirways creating Metrojet, Continental spin-offing Continental Lite and Delta creating Delta Express[20]. Recently, European carriers also decided to jump in the low-cost arena, as in the British Airways/Go, SAS/Snowflakes, KLM/Basiq Air cases, or, indirectly,

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[19] A typical example is provided by the Delta-AirTran case on some domestic routes out of Atlanta. In Europe, there is similar evidence on some routes to and from London.

[20] Delta Airlines have just started up a new low-cost subsidiary, called Song. This entity, however, is much more a JetBlue rather than a Southwest clone, operating from the same markets and targeting cost-conscious business travellers, most definitively women. Delta Express, instead, was the hypercompetitive answer by Delta to the invasion of the Florida market by Southwest, which the former unsuccessfully tried to imitate in its own business model.

with Lufthansa and the Germanwings experiment[21]. Moreover, the European environment provides evidence of the emergence of charter carriers' low-cost subsidiaries, like Hapag Lloyd Express or MyTravel Lite for MyTravel.

The survival ratio for low-cost subsidiaries, however, shows that most of them have actually failed[22]. In fact, it has proved very difficult to create a LLC inside a highly-unionised or rather conservative company without the same entrepreneurial spirit and scope of salary concessions that are being obtained by genuine low-cost start-ups. On a broader view, we can say that mingling complex and simple operations, each of which has distinct objectives and missions, often increases costs and lowers service standards of the whole company; there is evidence for this across the board for businesses, and is not industry-specific for airlines.

The second option is provided by the transformation of the entire traditional carrier into a LCC. This path of action naturally fits better in the case of a regional carrier, as it was successfully implemented in the case of the British operator FlyBe. Matters of dimensions and a lower cost-per-seat gap justify this statement. For instance, in Italy there is speculation that Eurofly, a charter carrier with a minor stock participation of Alitalia, is going to undertake a radical change and enter and fight within the low-cost arena. Volare, another Italian regional and charter carrier, has also announced that beginning in 2004 all of its services will be operated by Volareweb.com, the group's low-cost subsidiary.

Unfortunately, the transformation of a national full-service operator into a LCC, as in the case of rumours around SAS, is a Herculean task for management. Unions and employees will be unwilling to accept a salary reduction unless in the form of an employee stock ownership program (ESOP)[23] program. But the passage to the low-cost arena means that the traditional carrier will automatically leave most of its long-haul network, too. This decision will crash against governments' will to maintain an international visibility, with participation in an umbrella alliance being highly preferred to the (probably) higher revenue-generating low-cost option. Thus, many incumbent airlines will find this transformation difficult, with price-cutting measures becoming a short-term implementation and

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[21] Germanwings is the low-cost subsidiary of Eurowings. Lufthansa has some 25% of Eurowings share, with an agreement to grow up to 50%.

[22] This figure is related to the U.S market. European low-cost subsidiaries are very young, so it is too early to say that they are still on the market because of different conditions or because they have not yet had the time to fail.

[23] Employee Stock Ownership Programs (ESOP) have been widely used in the '90s for obtaining salary concessions. Today, there is literature that evidences that ESOPs have only created greater governance problems for their companies.

drastic cost reduction only a mirage. It is comes as no surprise that in the European low-cost environment we still find a lot of stuck-in-the-middle low-fares/high-cost airlines, like Meridiana in Italy, or the defunct Air Lib and Air Lib Express in France.

Ally

This could really become the next frontier for the whole airline business. What we still have not seen, however, is some sort of extensive contractual agreement between a traditional carrier and a low-cost carrier, the only exception being the limited route-based, block-space agreement between Virgin Express and Sabena. The advantages for both actors could be significant. The low-cost carrier could more easily grow in its target market. This process could be achieved by the help, without competition, of the traditional carrier, with the latter supporting the former, for instance, with public relations or in trade and commercial relationships.

The traditional airline could, instead, avoid a bloody fare war, preserving the value of its own scarce resources by transferring its own capacity on those routes that cannot be served by LCCs: like in the case of regional-feeder services and long-haul routes[24]. In the highly contestable, trunk medium-haul services its commercial presence would be guaranteed by block-space agreements, eventually, interlining those services with its own long-haul network[25].

Thus, as the process of market growth by LCCs continues, the ally option could be the most efficient and effective answer to cope with the changes of market boundaries. The fact that these alliance patterns are still not in action is not only result of LCCs targeting all possible customers in the growing phase of their product lifecycle; but also, because egotistic behaviours by traditional carriers' top managers and their belief that LCCs are simply transitory within the airline business. These are the real technical and human explanations for this option not being implemented.

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[24] Feeder and regional services are typically thin markets, where capacity needed is not that of LCCs for achieving their break-even load factors. Long-haul services, on the other hand, are immune from LCCs because on a long flight on-board comfort becomes a primary issue and even cost conscious passengers are unwilling to trade it for a low fare. For many routes, moreover, strict bilateral agreements and single-designation practices still protect the monopoly of traditional national carriers.

[25] Developing an on-line connection in the form of code-sharing between a traditional and a low-cost operator promises, instead, to be a very risky business. For instance, the superior quality image of the traditional operator could be diluted by the association with a low-cost operator.

CONCLUSIONS

The Darwinian process that many industry observers have long predicted for the world airline industry has not yet occurred, especially not in Europe. This aspect, when dealing with the European environment, is strictly linked with the clear protection that countries still provide to their flag carriers, either as shareholders or simply as a matter of pride. State aids, in various forms, are still at work, even if they were banned in the early 1990s. It is certainly true that the conditions that all airlines have had to cope with for the last two years were not only traumatic, but also totally unpredictable. Thus, many liquidity crises can be certainly related, at least partly, to these factors.

But, if the goal is to exit the current downturn cycle with a streamlined number of actors, and, in fact, with a stronger European industry, there is no more time to waste in the process of adapting traditional carriers' business pillars to current competition patterns. At the same time, the business model innovator will not stay still, but it will constantly work to figure out how it can do more for its customers, for example, by reducing cost structures and passing on some of the savings to customers.

In this sense, every traditional carrier has to evolve into a new type of airline capable of being centered on these five pillars of action:

1. ***Simple*** in its value proposition, with service diversity encouraged only when market needs ask for it, like in the long-haul sector;
2. ***Committed*** in its endless effort of cost reductions, as the only way to survive in the market, due to yields' erosions;
3. ***Proactive*** in its continued research of new cluster demands to match with existing products;
4. ***Consistent*** in its marketing approach, avoiding the temptation to raise short-term benefits in the form of lower prices for a lower service, for instance, whist privileging its own natural long-term view; and
5. ***Clear, transparent and effective*** when dealing with internal customers' relationships, as a labour-based service practice may only survive thanks to the consensus of its own employees.

We cannot say if Jan Carlzon's late 1980s prophecy that only four traditional carriers will survive in the New Millenium is still alive. What is certainly true is that the European market may sustain a significant number of airlines, as it is today, only if they are internally consistent with the current scenario and with a clear elective positioning in mind. Unfortunately, that is exactly what is currently missing from Europe's traditional carriers.

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AN APPLICATION OF THE METHODOLOGY FOR ASSESSMENT OF THE SUSTAINABILITY OF THE AIR TRANSPORT SYSTEM

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ABSTRACT

An assessment and operationalization of the concept of a sustainable air transport system is recognised as an important but complex research, operational and policy task. This paper represents an academic effort to properly address the problem of assessing the sustainability of an air transport system. In particular, the paper presents a methodology for assessment of the sustainability of an air transport system. This methodology is based on an indicator system related to particular dimensions of the air transport system's performance considered from the aspects of particular actors involved. Specific cases are selected to illustrate the application of the proposed methodology.

INTRODUCTION

What is a sustainable system? According to the numerous definitions, this should be a system whose absolute consumption of the non-renewable energy resources (fossil fuels) and emission of greenhouse gases do not increase over time. According to these criteria, a transport system is an unsustainable system (Daly, 1991; Whitelegg, 1993). Nevertheless, since a transport system also acts as a strong driving force for the economic development and social welfare, the above definition of sustainability,

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particularly in the long-term, needs to be refined by taking into account both the positive and negative impacts of the system. In such context, sustainability of a transport system could be considered as the growth of the differences between the positive and negative effects. Such development seems to be achievable by establishing a balance between the system effects. However, numerous conceptual and practical problems might emerge as barriers. One of the most important conceptual barriers seems to be a rather difficult estimation of the system's full effects mainly due to the diversity of approaches and methodologies. The main practical problem appears to be difficulty in globalising the policies for promoting the concept of sustainable development mainly due to the heterogeneity of performances of the system components and the necessity for permanently compromising the interests of particular actors (ATAG, 2000: 2000a; DETR, 2000, 2001; EC, 1997; ECMT, 1998; Hewett & Foley, 2000; Levison, Gillen, Kanafani & Mathieu, 1996; WCED, 1987).

This paper makes an academic effort in applying a methodology to the assessment of the sustainability of an air transport system (Janic, 2003). This methodology is based on the indicator system of sustainability reflecting the system's operational, economic, social and environmental dimension of performance[1] (FAA, 1996). The indicator system for each dimension of performance contains the individual indicators and their measures defined with respect to the expected objectives and preferences of the actors involved such as users (air travellers), air transport operators, aerospace manufacturers, local communities, governmental authorities at different levels (local, national, international), international air transport associations, pressure groups and the public. By using the relevant inputs based on the structure of the indicator systems and particular measures, an assessment of the current level of sustainability of an air transport system with respect to the particular indicators and measures is carried out (EC, 1999).

THE CONCEPT OF SUSTAINABLE AIR TRANSPORT SYSTEM

Basic Principles of Sustainability

In light of the refined definition of sustainability, an air transport system could be considered sustainable if the net benefits of its operations increase with increasing of the system output either in the absolute (total) or relative terms (per unit of output). The net benefits are the sum of the differences

[1] This is an analogous definition to the definition that a sustainable society is supposed to have three essential dimensions of performance: economic, social, and environmental (United Nations, 1992).

between the positive effects (benefits) and the negative impacts (costs) at different geographical scales such as global (intercontinental), regional (national/continental), and local (community; INFRAS, 2000).

Sustainability at the global scale

At the global scale, the growth of economy and air transport demand have been strongly driven by each other with the evident negative consequences in terms of the absolute increase in energy (fossil fuels) consumption and global emission of greenhouse gases. In such a context, several options are thought to be useful to drive the system towards sustainable development—that is, to setting up and maintaining trade-offs between the positive effects and negative impacts—as follows (Janic, 2003).

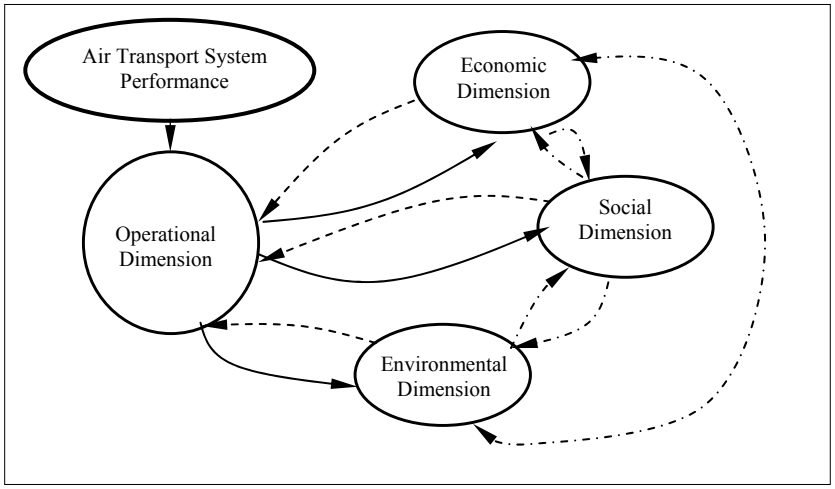
1. *Constraining the system growth at global scale*, which would include setting up an absolute limit to growth of the air transport demand and consequently to growth of the associated negative impacts;
2. *Setting up a cap on the impacts*, which would limit the system's energy consumption, associated air pollution, and thus indirectly the system's growth itself (Hewett & Foley, 2000);
3. *Decoupling the growth of the system demand and the economic growth*, which would include weakening of the strong links between the air transport demand and GDP (Gross Domestic Product). This has seemed to be able to be carried out by stimulating people to change their habits in the long-term (EC, 1999); and
4. *Trading-off between global effects and impacts,* which as a compromise scenario would provide mechanisms for the faster growth of the system's long-term global positive effects than the negative impacts.

Sustainability at the regional scale

At a regional (national, continental) scale, particularly in the U.S. and Western Europe, the growth of air transport demand has been additionally driven by local forces such as the liberalisation of air transport market(s), increasing of the system's productivity and diminishing of airfares. Such growth has been confronted with the limited capacity of airports and ATM/ATC (Air Traffic Management/Air Traffic Control) resulted in raising congestion and compromising the expected efficiency and effectiveness of air transport services. Under such circumstances, a balance between the system's growth and the associated negative impacts seems to be able to be achieved through three scenarios as follows (Janic, 2003):

1. *Affecting regional demand-driving forces*, which would as a controversial scenario discourage further growth of air transport demand by affecting the factors supporting market liberalisation and competition, productivity, and airfares (Boeing, 2001).
2. *Constraining the infrastructure expansion,* which as a do nothing scenario in terms of further expansion of the air transport infrastructure under conditions of growing demand could lead to a widespread and severe deterioration of the efficiency and effectiveness of service. In turn, such development might deter both existing and prospective users (EUROCONTROL, 2001).
3. *More efficient utilisation of the available infrastructure*, which could lead to improvements of utilisation of existing airport and ATM/ATC infrastructure capacity by using innovative technologies and operational procedures, modifications of the airlines' operational practice, and co-operation with other transport modes (particularly railways; Arthur, 2000).

Figure 1: Dimensions of performance of the air transport system and their linkages



Sustainability at the local scale

At the local scale, the positive effects and the negative impacts of growth of individual airports need to be balanced according to the following scenarios (Janic, 2003):

1. *Constraining the airport growth*, which would include constraining the available land for an airport's physical expansion, which in turn could compromise its further growth[2].
2. *Management of the airport growth*, which would include provision of the higher rates of increase of the total local benefits than costs of the associated impacts (BA, 2001).

Dimensions of the System Performance

Definition of the indicator system of sustainability of the air transport system can be carried out with respect to the operational, economic, social, and environmental dimension of performance[3]. The particular dimensions of performance have been dependent on each other, but the operational dimension has mostly influenced the other three. Figure 1 illustrates a generic scheme of these relationships (Janic, 2003).

The operational dimension is the basic one, which relates to the characteristics of the system demand, capacity, effectiveness, safety and security of service (Janic, 2003).

The economic dimension relates to the system's operating revenues, costs and productivity (Hooper & Hensher, 1997).

The social dimension relates to the social effects such as the system's direct and indirect contribution to employment and GDP at the local and regional scale (Button & Stough, 1998; DETR, 1999; 2000). In addition, contributions to globalisation and internalisation of business and leisure activities (international trade, investments, tourism) could be taken into account.

The environmental dimension relates to the system's physical impacts on the people's health and the environment in terms of the local (airport) and global (airspace) air pollution, airport noise, aircraft accidents, congestion, generation of waste and land use (Janic, 1999).

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[2] For the first time, at the Amsterdam Schiphol airport, the government has limited by law the maximum annual number of aircraft movements aimed at controlling the noise. Consequently, in 1998 the maximum number of aircraft movements has been restricted to 380,000 with possible annual increase of 20,000 until 2003 (Boeing, 2001; Offerman & Bakker, 1998).

[3] Some studies consider only three dimensions of air transport system performance: economic, social, and environmental (INFRAS, 2000).

The Actors, Their Objectives and Preferences

According to the structure of an air transport system, the following main actors may be involved in dealing with the sustainability as follows (ATAG, 2000; INFRAS, 2000):

1. *Users of services,* such as air travellers and shippers of freight and mail constituting the air transport demand;
2. *Air transport operators,* providing the system's services by using the related infrastructure, facilities and equipment such as airports, ATM/ATC, and airlines;
3. *Aerospace manufacturers,* producing the aircraft, ATM/ATC, and airport facilities and equipment;
4. *Local community members,* which is the population living in the vicinity of airports;
5. *The governmental bodies,* playing the role in creation of the institutional regulation for the system's operation at the local (community) and central (national) levels;
6. *Aviation organisations,* co-ordinating the system's development at the global (international) scale;
7. *Lobbies and pressure groups,* articulating the interests of people who may be for or against an expansion of the air transport system infrastructure; and
8. *The public,* temporarily interested in the specific aspects of the system operations.

Figure 2 shows a simplified structure of the air transport system used for development of the indicator system as the methodology for assessment of sustainability.

Sustainability of the air transport system may have different meaning and contents for the particular actors, which are summarised as follows:

1. The *users—air travellers* and *shippers of freight* and *mail*—usually prefer frequent, easily accessible, low cost, punctual, reliable, safe and secure services.
2. The *air transport operators* prefer services according to their business objectives in terms of profitability, safety and security and the users' preferences.
3. The *aerospace manufacturers* prefer smooth selling of their reliable, safe, and profitable products to the system operators.
4. *Local community members* usually tend to maximise the benefits and minimise the costs of an air transport system at the local scale. The employment opportunity and use of efficient air connections to other distant communities or regions can be considered as the obvious benefits. The costs are regarded as

exposure to the airport noise, air pollution, and risk of injury, loss of life and damage of property due to aircraft accidents.

5. *Local* and *central government(s)* are mostly interested in the system's overall benefits and externalities. Direct benefits may include the system's contribution to local and national employment and GDP. Indirect benefits may embrace contributions to internalisation and globalisation of manufacturing, trade, investments and tourism. Externalities may be of interest while creating local and global policies and legislation to protect the people's health and environment.
6. *International aviation organisations* such as International Civil Aviation Organisation (ICAO), International Air Transport Association (IATA), European Civil Aviation Conference (ECAC), Association of European Airlines (AEA) and Airport Council International (ACI) provide the framework and guidelines for coordinated development of the system at both the regional and global scale.
7. *Different lobbies and pressure groups* organise campaigns against globally harmful effects of the polluting systems on the people's health and environment. In this role, they also intend to prevent further contribution of the air transport system to global warming by strong opposition, sometimes together with local community people, to the physical expansion of the system infrastructure, that is, airports.
8. *The public* uses media such as radio, television, the Internet and newspapers to get information about the system. This interest is strengthening in the cases of launching innovations (aircraft, airports), severe disruptions of services and air accidents, and changes of airfares. In general, information about the system should be available to public at any time.

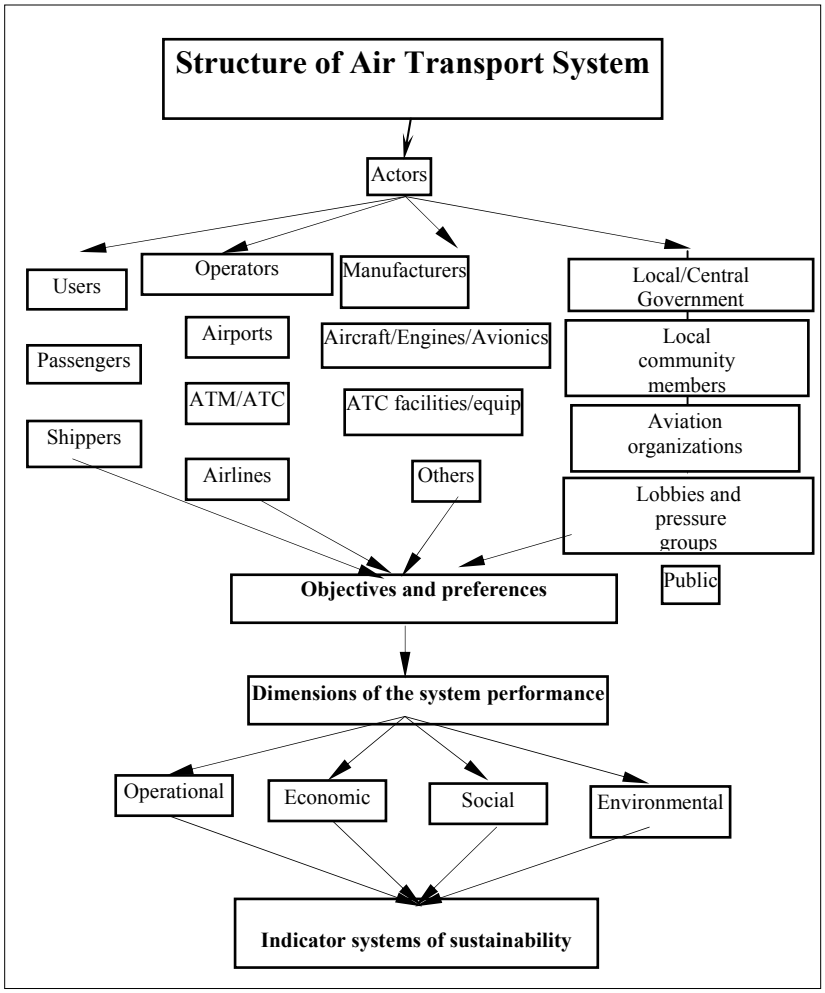
THE INDICATOR SYSTEM OF SUSTAINABILITY

General

The indicator system of sustainability of an air transport system has been defined to measure the effects (benefits) and impacts (costs), in either absolute or relative monetary or non-monetary terms, as functions of the relevant system output (Janic, 2003). In such a context, the system has been assumed to be sustainable if, with an increase of the relevant system output, the measure of one indicator reflected the relative effects has increased and

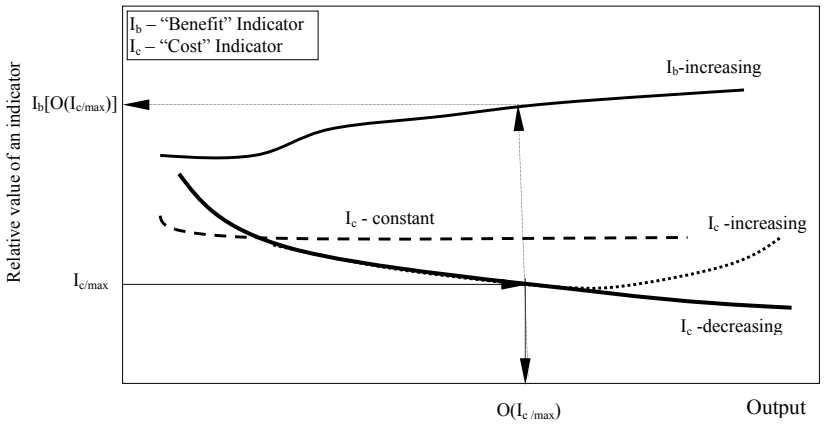
the measure of another indicator reflected the relative impacts has decreased (or been constant, and vice versa). Figure 3 shows a generic scheme[4].

Figure 2: Structure of the air transport system for assessment of sustainability



[4] Setting up a limit on the particular indicator may have a two-fold effect. For example, if the cost indicator is limited to $I_{c/max}$, the output will be able to rise maximally to $O(I_{c/max})$. Such constrained output will affect a benefit indicator, which will be allowed to rise maximally to $I_b[O(I_{c/max})]$. Consequently, setting up the criteria on indicators should always include balancing between the effects and impacts.

Figure 3: Relationships between the sustainability indicators and the air transport system's output



STRUCTURE OF THE INDICATOR SYSTEM

Different actors might use different indicators for assessment of the system's sustainability with respect to the particular dimensions of the system performance and their specific objectives and preferences. The indicator system consisting of the individual indicators and their measures are valid for the given period of time (day, month, year; Janic, 2003).

Indicators for users–air travellers

The indicator system for users—air travellers—consists of eight individual indicators related to the airports and airlines operated at different scales.

Operational indicators

The indicators of the operational dimension of performance are identified as follows:

1. *Punctuality* of service is measured by the probability that a flight will be on time and the average delay per flight[5] (Headley & Bowen, 1992; USDT, 2001). Users usually prefer

[5] Usually, delays are categorized as arrival and departure delays, which may be shorter or longer than 15 minutes (EUROCONTROL, 2001; USDT, 2001).

the former measure to be as high as possible and the latter one as low as possible with increasing of the number of flights.

2. *Reliability* of service is measured as the ratio between the realised and the total number of flights (USDT, 2001). The measure is preferred to be as high as possible and to increase with increasing of the number of flights.
3. *Ratio of lost/damaged baggage* is expressed as the proportion of the lost (or damaged) baggage compared to the total number of passengers served. This measure is preferred to be as low as possible and to decrease with increasing of the number of passengers.
4. *Safety* is measured as the ratio of the number of deaths (or injuries) per unit of output—Revenue Passenger Kilometer or Revenue Passenger Mile (RPK or RPM). The users prefer this measure to be as low as possible and to decrease with increasing of RPK or RPM.
5. *Security* is measured as the ratio between the number of detected illegal dangerous devices and the total number of passengers screened. It is preferred to be as low as possible and to decrease with increasing of the number of passengers.

Economic indicator

The indicator of the economic dimension of performance is identified as follows:

1. *Economic convenience of service* is measured by the average airfare per passenger, which is preferred by users to be as low as possible[6].

Social indicator

The indicator of the social dimension of performance is identified as follows:

1. *Spatial convenience of service* is measured by the number and diversity of destinations and flights at an airport with respect to type of destination, connectivity (non-stop, one-stop or multi-stop) and trip purpose (business, leisure). In general, users prefer this measure to be as high as possible.

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[6] Some airfares charged by low-cost air carriers in Europe and the U.S. may represent the exceptions from this general rule.

Environmental indicator

The indicator of the environmental dimension of performance is identified as follows:

1. *Comfort* and *healthfulness* at airports is measured by the number of passengers per unit of the available space and the average queuing time (Hooper & Hensher, 1997; Janic, 2001). Configuration and size of seats in the economy class[7] and the quantity of fresh air delivered to the passenger cabin per unit of time is used to measure the passenger comfort. The airport measures are preferred to be as low as possible and to decline with increasing of the number of passengers served. The measures while onboard are preferred to be as high as possible**.**

Indicators for airports

The indicator system for airports consists of eleven indicators related to one or a set of airports in a given region (Janic, 2003).

Operational indicators

The indicators of the operational dimension of performance are identified as follows:

1. *Demand* has been expressed as the number of passengers and the number of ATMs and is preferred to be as great as possible and to match the available capacity.
2. *Capacity* is measured as the maximum number of passengers and the maximum number of ATMs. Both measures are preferred to be as high as possible and to match growing demand (Janic, 2001).
3. *Quality of service* is measured by the average delay per ATM or per passenger occurring whenever the demand exceeds the capacity. The measure is preferred to be as low as possible and to decrease with increasing of demand (Janic, 2001).
4. *Flexibility of using the available capacity* is measured by the ratio between the number of substituted flights by other transport modes and the total number of flights[8]. This ratio is

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[7] Configuration of the economy class seats on long-haul flights has recently emerged as a matter of concern due to cases of passenger deaths caused by DVT (Deep Vein Thrombosis).

[8] For example, three European super hubs, Frankfurt Main, Paris Charles De Gaulle and Amsterdam Schiphol are connected to a High Speed Rail Network. Partial substitution of short-haul flights has already taken place there (EC, 1998; HA, 1999; IFRAS, 2000). If the air-rail

preferred to be as high as possible and to increase with increasing of the number of flights.

Economic indicators

The indicators of the economic dimension of performance are identified as follows:

1. *Profitability* is measured by the operating profits (the difference between operating revenues and operating costs) per unit of the airport output–an ATM or a passenger (Doganis, 1992). This measure is preferred to be as high as possible and to increase with increase in the airport output.
2. *Labour productivity* is expressed by the number of ATMs, passengers or workload unit per (WLU) employee[9] (Doganis, 1992; Hooper & Hensher, 1997). This measure is preferred to be as high as possible and to increase with increasing of the number of employees.

Social indicators

No indicators of the social dimension of performance are identified.

Environmental indicators

The indicators of the environmental dimension of performance are identified as follows:

1. *Energy efficiency* is measured by the quantity of energy consumed per unit of the airport output–an ATM or a passenger. This measure is preferred to be as low as possible and to decrease with increasing of airport output.
2. *Noise efficiency* is expressed by the area in square kilometres determined by the equivalent noise level in decibels (DETR, 2000; 2001). This indicator is preferred to be as small as possible and to diminish with increasing of the number of ATMs.
3. *Air pollution efficiency* is measured by the air pollutants emitted per an event–landing/take-off (LTO)[10] cycle (EPA, 1999; ICAO, 1993a). This measure is preferred to be as low as

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substitution were carried out without filling in freed slots by long-haul flights, congestion and associated local and global air pollution, and noise would be reduced. Under such circumstances, this indicator could be classified as an environmental indicator.

[9] In many cases, workload unit (WLU) has been used as an equivalent for one passenger or 100 kg of baggage (Doganis, 1992)

[10] ICAO has recommended the landing/take-off (LTO) cycle as a standardised format for quantifying air pollution at airports (ICAO, 1993a)

possible and to decrease with increasing of the number of LTO cycles.

4. *Waste efficiency* is measured by the quantity of waste per unit of the airport output–an ATM or a passenger (BA, 2001). The measure is preferred to be as low as possible and to decrease with increasing of the airport output.
5. *Land use efficiency* is measured in terms of the area of land used for accommodating air transport demand. The measure is preferred to be as low as possible and to increase with increasing of the volume of demand.

Indicators for ATM/ATC

The indicator system for ATM/ATC consists of eight indicators, which might be quantified for a part of the ATM/ATC sector or for the whole system (airspace of a country, a wider region, or continent; Janic, 2003).

Operational indicators

The indicators of the operational dimension of performance are identified as follows:

1. *Demand* is measured as the number of flights demanded to pass through a given ATM/ATC airspace (Janic, 2001). This measure is preferred to be as great as possible.
2. *Capacity* is measured by the maximum number of flights served in a given airspace per unit of time (Janic, 2001). This indicator is preferred to be as great as possible and to increase with increasing demand.
3. *Safety* is measured by the number of aircraft accidents or the number of Near Midair Collisions (NMAC) per unit of the ATM/ATC output (controlled flight). Both measures are preferred to be as low as possible and to decrease with increasing of the number of flights.
4. *Punctuality of service* is measured by the proportion of flights being on-time and the average delay per delayed flight due to the ATM/ATC restrictions. While the former measure is preferred to be as high as possible and to increase, the latter measure is preferred to be as low as possible and to decrease with increasing of the number of flights.

Economic indicators

The indicators of the economic dimension of performance are identified as follows:

1. *Cost efficiency*[11] is measured by the average cost per unit of output (controlled flight). The measure is preferred to be as low as possible and to decrease with increasing of the number of flights (Janic, 2001).
2. *Labour productivity* is reflected the number of controlled flights per an employee. This measure is preferred to be as high as possible and to increase with increasing of the number of employees.

Social indicators

No indicators of the social dimension of performance are identified.

Environmental indicators

The indicators of the environmental dimension of performance are identified as follows:

1. *Energy efficiency* is measured by the extra fuel consumption per flight due to deviations from the prescribed (fuel-optimal) trajectories dictated by the ATM/ATC. The indicator is preferred to be as low as possible and to decrease with increasing of the number of flights.
2. *Air pollution efficiency* is measured by the average quantity of pollutants per flight caused by the extra fuel consumption. The indicator is preferred to be as low as possible and to decrease with increasing of the number of flights.

Indicators for airlines

The indicator system for airlines consists of eleven indicators, which can be quantified for an individual airline, airline alliance or the whole airline industry of a given region, country or continent (Janic, 2003).

Operational indicators

The indicators of the operational dimension of performance are identified as follows:

1. *Airline size* is expressed by the volume of RTK or RTM, the number of flights, the number of passengers and/or the size of the resources used in terms of the number of aircraft and staff

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[11] Cost is considered to be a more relevant indicator than profitability because most ATM/ATC providers charge their services on the cost-recovery principle. For example, EUROCONTROL member States and ATM providers from Canada, Australia, New Zealand, South Africa, etc., fully recover their costs by charges (INFRAS, 2000).

(Janic, 2001). The above measures are preferred to be as great as possible and to increase over time and under conditions of sufficient demand.

2. *Load factor* is measured as the ratio between the total RTK or RTM and Available Ton-Kilometre or Available Ton-Mile (ATK or ATM). This measure is preferred to be as great as possible and to increase with increasing of the airline output (Janic, 2001).
3. *Punctuality, reliability* and *safety* of service for airlines are measured and preferred analogously to that of users as described above (Janic, 2001).

Economic indicators

The indicators of the economic dimension of performance are identified as follows:

1. *Profitability* is measured by the average profits (difference between the operating revenues and costs) per unit of output—RTK or RTM. This measure is preferred to be as great as possible and to increase with increasing of the airline output.
2. *Labour productivity* is measured by the average quantity of output—RTK or RTM—per employee. This measure is preferred to be as great as possible and to increase with increasing of the number of employees.

Social indicators

No indicators of the social dimension of performance have been identified.

Environmental indicators

The indicators of the environmental dimension of performance are identified as follows:

1. *Energy* and *air pollution efficiency* are measured by the average quantity of fuel and associated air pollution, respectively, per unit of output—RTK or RTM, distance flown or the number of flying hour. Both measures are preferred to be as low as possible and to decrease with increasing of output.
2. *Noise efficiency* is measured by the proportion of the aircraft of Stages 3 and 4 in an airline fleet. This measure is preferred to

be as great as possible and to increase with expansion of the airline fleet[12] (BA, 2001; ICAO, 1993b).

3. *Waste efficiency* is measured by an average quantity of waste per unit of the airline output—RTK or RTM. This measure is preferred to be as low as possible and to diminish with growing of the airline output (BA, 2001).

Indicators for aerospace manufacturers

The indicator system of the airspace manufacturers consists of eight indicators (Janic, 2003).

Operational indicators

The indicators of the operational dimension of performance are identified as follows:

1. *Aircraft innovations* is measured by technical productivity, resource use and cost efficiency (RAS, 2001). The first measure, preferred to be as high as possible, is expressed as the product between the aircraft speed and capacity product (ton-kilometres per hour or ton-miles per hour). The second measure, preferred to be as low as possible, is expressed by the amount of resources used for installment of a unit of aircraft capacity (i.e., in terms of aircraft weight per seat; Lowson, 2001). The last measure, preferred to be as low as possible, is expressed by the average operating cost per unit of capacity—ATK or ATM (Arthur, 2000; Janic, 2001).
2. *Innovations* of *ATM/ATC* and *airport facilities* is measured by the cumulative navigational error of an aircraft position, and the capacity of facilities used for processing demand at airports, respectively. The former measure is preferred to be as small as possible and the latter one as high as possible (Arthur, 2000; Janic, 2001).
3. *Reliability of structures* is measured by the rate of failures of the particular components per unit of time. Due to the safety and operational reasons, this measure, is preferred to be as high as possible.

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[12] Once an airline fleet is completely modernized by replacing all aircraft of Stage 2 by the aircraft of noise category 3 and 4, this indicator will become irrelevant.

Economic indicators

The indicators of the economic dimension of performance are identified as follows:

1. *Profitability* is measured by the average operating profits (the difference between operating revenues and costs) per unit sold. This measure is preferred to be as great as possible and to increase with increasing of the number of units.
2. *Labour productivity* is measured by the average number of units produced per employee. The measure is preferred to increase with increasing of the total number of employees.

Social indicators

No indicators of the social dimension of performance are identified.

Environmental indicator

The indicator of the environmental dimension of performance is identified as follows:

1. *Energy, air pollution* and *noise efficiency* is measured by the absolute or relative decrease in the fuel consumption, air pollution or noise per unit of engine power or unit of an aircraft operating weight. These measures are preferred to be as low as possible and to decrease with increasing of the engine power and/or aircraft operating weight.

Indicators for local community

The indicator system for the local community consists of four indicators of sustainability (Janic, 2003).

Operational indicators

No indicators of the operational dimension of performance are identified.

Economic indicators

Indicators of the economic dimension of performance have not been identified.

Social indicators

The indicator of the social dimension of performance is identified as follows:

1. *Social welfare* is measured by the ratio between the number of people employed by the air transport system and the total number of employed people within the local community. This measure is preferred to be as high as possible and to increase with increasing of employment within the local community (DETR, 1999).

Environmental indicators

The indicators of the environmental dimension of performance are identified as follows:

1. *Noise disturbance* is measured by the total number of disturbing noise events—ATMs—during a given period of time (day, month, year) and by the number of complaints per noise event—ATM. Both measures are preferred to be as low as possible and to decrease with increasing of the number of ATMs.
2. *Air pollution* is measured as the ratio between the amounts of air pollutants emitted by the air transport system and the total amount of pollutants emitted by all other local sources. This indicator is preferred to be as low as possible and to decrease with increasing of the total air pollution.
3. *Safety* is measured by the number of aircraft accidents per ATM which affect the local community people in terms of damaging their property, making injuries or losing their life. This measure is preferred to be as low as possible and to decrease with increasing of the number of ATMs.

Indicator system for local and central governments

The indicator system for local and central government consists of seven indicators (Janic, 2003):

Operational indicators

No indicators of the operational performance are identified.

Economic indicators

The indicators of the economic dimension of performance are identified as follows:

1. *Economic welfare* is measured by the proportion of GDP obtained by the air transport sector in the total GDP. This measure is preferred to be as great as possible and to increase with increasing of the total GDP.

2. *Internalisation/globalization* is measured by the proportion of trade in terms of the volume and/or value of export and import carried out by the air transport in the total regional (country) trade, and by the ratio between the number of air trips and the total number of trips in a given region (country). These measures are preferred to be as great as possible and to increase with increasing of the volume of trade and the total number of trips, respectively.
3. *Externalities* are measured by the average expense per unit of the system output—RPK or RPM—due to either preventing or remedying the particular impacts such as noise, air pollution, air incidents/accidents, and sometimes congestion (DETR, 2001; EC, 1997; Janic, 1999; Levison et. al, 1996; Ying-Lu, 2000). This measure is preferred to be as low as possible and to decrease with increasing of the system output.

Social indicator

The indicator of the social dimension of performance is identified as follows:

1. *Overall social welfare* is measured as the ratio between the number of employees within the air transport sector and the total number of employees in a region (country). This measure is preferred to be as high as possible and to increase with increasing of the total employment in a given region.

Environmental indicators

The indicators of the environmental dimension of performance are identified as follows:

1. *Global energy efficiency* us measured by the average amount of fuel consumed per unit of the system output–RTK or RTM. This measure is preferred to be as low as possible and to decrease with increasing of the system output.
2. *Global noise disturbance* is measured by the total number of people exposed to the air transport noise during given period of time (year). The measure is preferred to be as low as possible and to decrease over time.
3. *Global air pollution* is measured by the total emissions of air pollutants per unit of the system output—RTK or RTM. This measure is preferred to be as low as possible and to diminish with increasing of the system output.
4. *Global land use* is measured as the ratio between the land used for installing the air transport infrastructure and the total land

used for installing the infrastructure of the whole transport system of a given region (country). This measure is preferred to be as low as possible and to decrease with increasing of the area of land acquired for transport infrastructure.

Table 1: Indicators used for assessment of the sustainability of an air transport system

Actor	Dimension of the System Performance	Indicator
Users		
	Operational	Punctuality
		Reliability
		Lost & damaged baggage
		Security
	Economic	Economic convenience
ATM/ATC		
	Operational	Punctuality
		Reliability
	Economic	Productivity
	Environmental	Energy (fuel) efficiency
Aerospace Manufacturers		
	Operational	Technical productivity
		Efficiency
	Environmental	Fuel efficiency
		Noise efficiency
Local community members		
	Environmental	Noise disturbance
Governments		
	Economics	Economic welfare
		Internalisation/Globalization
	Social	Overall social welfare
	Environmental	Global energy efficiency
		Global noise disturbance
		Global air pollution

APPLICATION OF THE PROPOSED METHODOLOGY

Fifty-eight indicators and sixty-eight measures have been defined in the scope of the indicator system developed for seven groups of actors—users

(air travellers), the system operators (airports, airlines and ATM/ATC), airspace manufacturers, local community members, and local and central government. Twenty-six indicators and measures are estimated in order to illustrate existence of the sustainability of an air transport system. The list is given in Table 1.

Data for estimating the particular indicators and their measures are extracted from different secondary sources. The results are shown in Figures 4, 5, 6, 7, 8, 9 and 10. In all these Figures the dots represent empirical data and the lines indicate global direction of development over the mentioned period of time (i.e., trend).

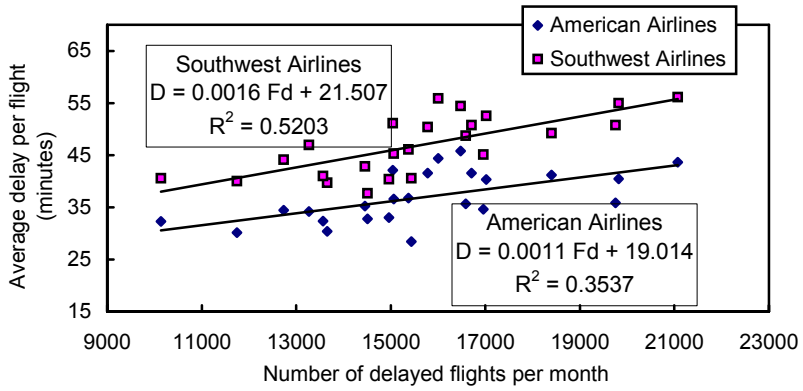
Users

Figure 4a illustrates punctuality of American and Southwest Airlines (U.S). As can be seen, at both airlines the average delay per delayed flight increased with increasing of the number of delayed flights. As well, the average delay of a Southwest flight was longer than the average delay of an American flight, independent of the number flights carried out. Consequently, users might have a better perception of punctuality of American than Southwest Airlines, but in general, they both are unsustainable according to this indicator.

Figure 4b illustrates reliability of two U.S. airlines, American and Southwest, as a proportion of the cancelled flights relative to the total number of flights carried out per month. As can be seen in the given example, at American this proportion varied between 2% and 6% and generally decreased with increasing of the number of flights. At Southwest, it varied between 0.5% and 2% and was nearly constant with increasing of the number of flights. As well, Southwest performed a greater number of flights than American. From the above example, it seems that the airlines with a greater number of flights also tended to provide a higher reliability of services, which according to the users' perception, makes them more sustainable.

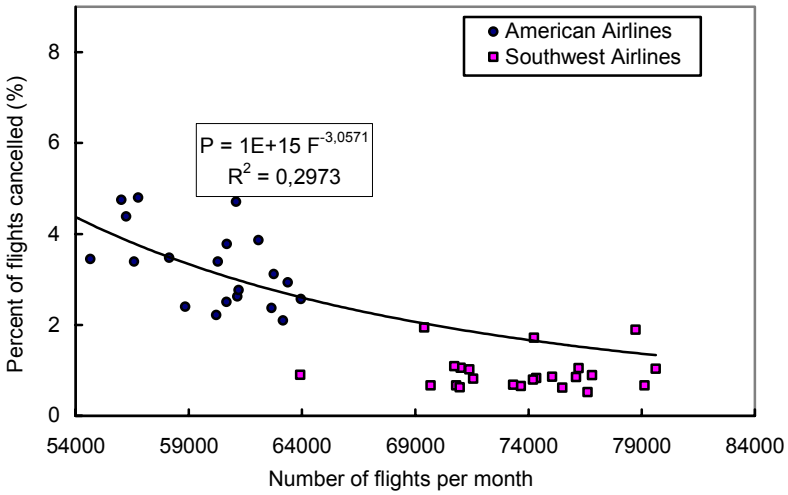
Figure 4c illustrates the ratio of mishandled (lost and damaged) baggage in relation to the total number of domestic passengers accommodated at U.S. airports. As can be seen, this ratio varied between 5.0% and 6.5% and decreased with increasing of the number of passengers up to about 460 million. Above this number, the ratio starts to increase with increasing of the number of passengers, which indicates worsening of the performance. From the users' perspective, according to the variations of this indicator, the system is sustainable with increasing of the number of passengers to a certain limit, and unsustainable beyond that limit.

Figure 4a. Punctuality of some U.S. airlines, 1999-2000



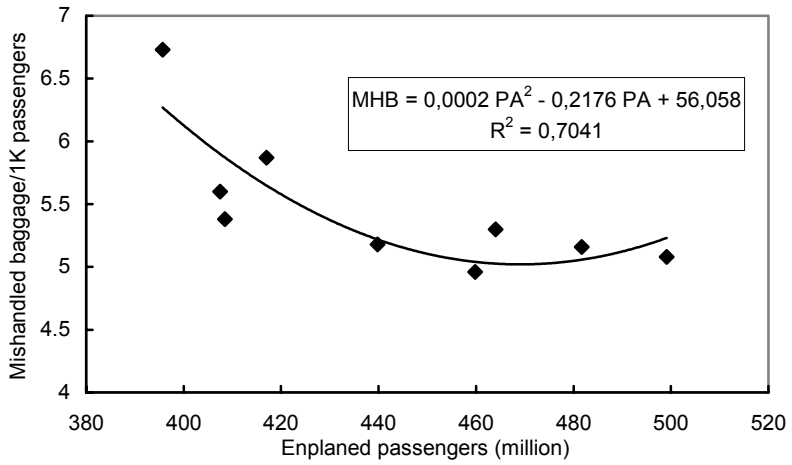
Data compiled from: *Major Airport Flight Delay*. (2001). Washington DC, USA/U.S. Department of Transportation Office of Airline Information.

Figure 4b. Reliability of some U.S. airlines, 1999-2000



Data compiled from: *Major Airport Flight Delay*. (2001). Washington DC, USA/U.S. Department of Transportation Office of Airline Information.

Figure 4c. Lost and damaged (mishandled) baggage for U.S. domestic scheduled services, 1990–1999

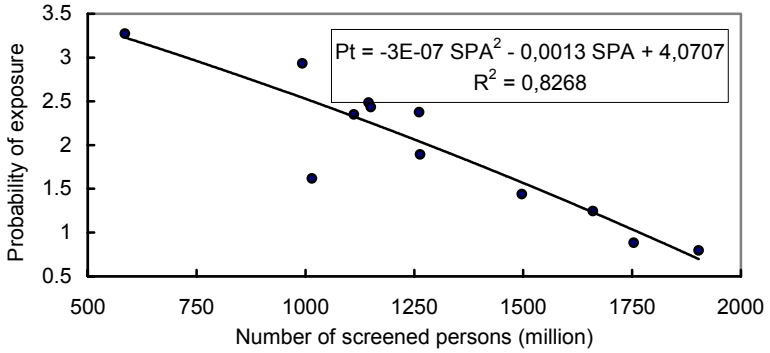


Data compiled from: *Major Airport Flight Delay.* (2001). Washington DC, USA/U.S. Department of Transportation Office of Airline Information.

Figure 4d illustrates security at U.S airports expressed by the probability of being exposed to the threat of illegally carried dangerous devices in relation to the number of passengers screened per year. As can be seen, this probability decreased with increasing of the number of screened passengers. This indicates the system's long-term sustainability with respect to this indicator. Nevertheless, one has to be cautious with this measure since the very low risk hides a vital threat with the potential to materialize into events with serious consequences such as the September 11, 2001, terrorist attacks on the U.S.

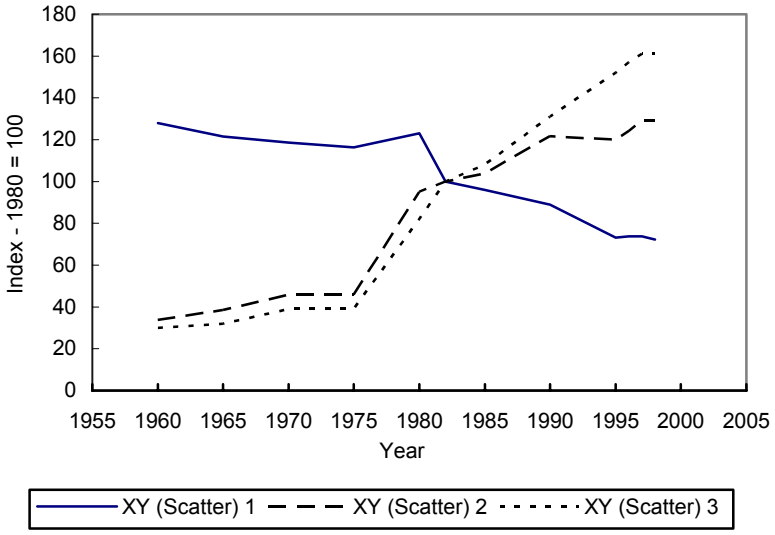
Figure 4e illustrates the economic convenience of air transport services for U.S. air transport system users expressed by average airfares and Consumer Price Index (CPI) during the observed period. As can be seen, two periods have been evident: the first period, between 1960 and 1982, when the index of airfares was above the index of CPI; the second period, from 1983 on, when the index of CPI was below the index of the airfares. The main forces of such changes consist of the positive developments in the U.S. aviation market after deregulation in 1978 and of an overall socio-economic progress. In addition, in an absolute sense, airfares have been more or less permanently decreasing, particularly since 1983, which might illustrate long-term system sustainability according to this indicator.

Figure 4d. Probability of being exposed to a threat at U.S. airports, 1980–1999



Data compiled from: *Major Airport Flight Delay*. (2001). Washington DC, USA/U.S. Department of Transportation Office of Airline Information.

Figure 4e. Economic convenience of the U.S. air transport system, 1960-1999

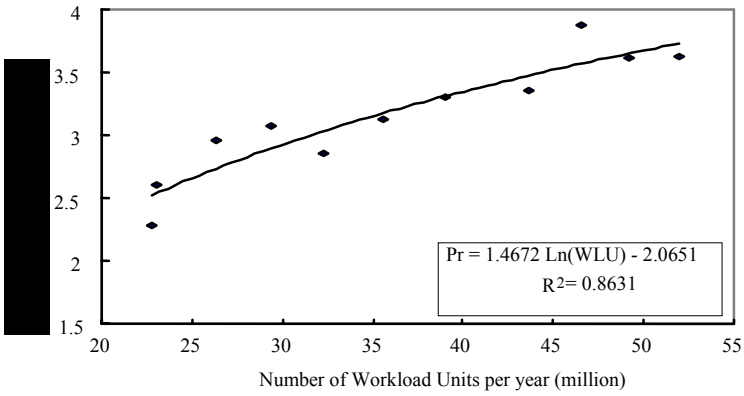


Data compiled from: *Major Airport Flight Delay*. (2001). Washington DC, USA/U.S. Department of Transportation Office of Airline Information.

Airports

Figure 5a illustrates profitability of Amsterdam Schiphol airport (Netherlands). The profitability is the difference between the revenues and costs in terms of euros per WLU is related to the total annual number of WLU accommodated at the airport. As can be seen, this profitability increased with increasing of the number of WLU at a decreasing rate. In the given example, existence of long-term airport sustainability is indicated with respect to this indicator.

Figure 5a. Profitability of Amsterdam Schiphol airport, 1990-2000



Data compiled from: *Annual Community Report.* (2000). Schiphol, The Netherlands/Schipol Group.

Figure 5b illustrates labor productivity at Amsterdam Schiphol airport (Netherlands). This productivity is in terms of the number of WLU per employee related to the total number of WLU accommodated at the airport per year. As can be seen, during the observed period, this productivity generally increased with increasing of the number of WLU, but at a decreasing rate, which turned into zero after the number of WLU increased over 45 million per year. Such development indicates how sustainability of the system vanished with respect to this indicator during this period of growth.

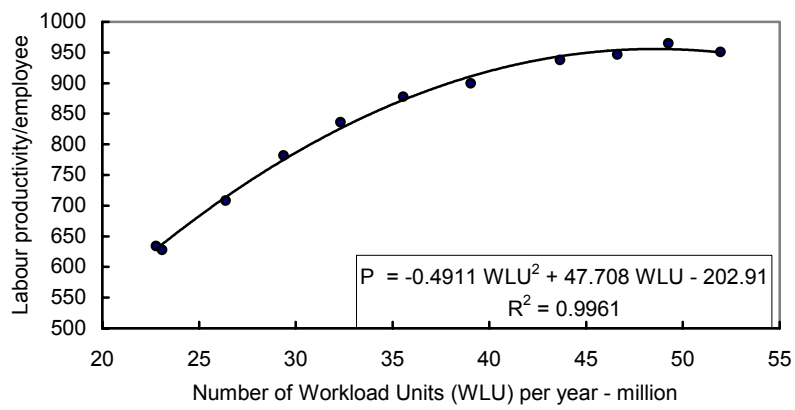
Figure 5c illustrates noise efficiency at Frankfurt airport (Germany) expressed by the area of land covered by the equivalent constant sound level L_{eq} [= 62, 67 and 75 dB(A)] in relation to the annual number of ATMs. As can be seen, for a given number of ATMs, for larger L_{eq} this area was smaller, and vice versa, which was intuitively expected. As well, the area of land affected by given L_{eq} decreased with increasing of the number of

ATMs. Both measures indicate that the area around the airport exposed to a given level of noise generally decreased despite increasing of the traffic volume. This certainly was achieved by replacing noisier aircraft with quieter aircraft and modifications of the operational procedures at and around the airport. Consequently, according to this indicator the airport has developed in a sustainable way.

Figure 5d illustrates air pollution efficiency of the Zurich airport (Switzerland) expressed by the quantity of N_{ox} per LTO cycle in relation to the number of LTO cycles carried out. As can be seen, this efficiency was achieved by decreasing the emission despite increasing of the number of LTO cycles, primarily through modernization of the aircraft fleet. However, this emission started to increase when the number of LTO cycles exceeded 150 thousands, primarily due to more intensive use of the larger aircraft. This clearly indicates compromising of the already achieved sustainability trend.

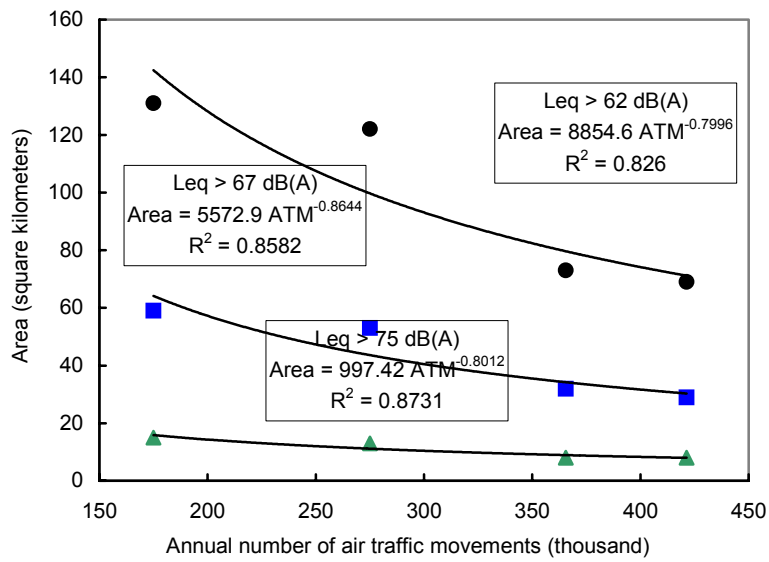
Figure 5e illustrates waste efficiency in terms of the quantity of waste per passenger in relation to the annual number of passengers accommodated at Frankfurt Main (Germany) and three London airports (Heathrow, Stansted, Gatwick, UK). As can be seen, this quantity decreased at Frankfurt Main and increased at London airports with increasing of the annual number of passengers, which indicates their sustainable and unsustainable development, respectively, with respect to this indicator.

Figure 5b. Labour productivity at Amsterdam Schiphol airport, 1990-2000



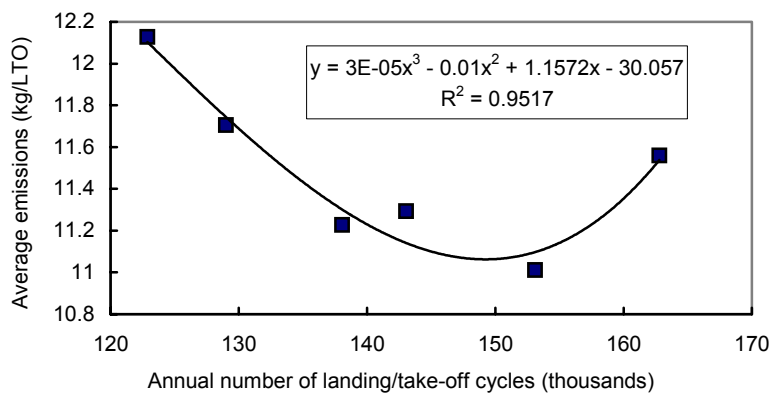
Data compiled from: *Annual Community Report.* (2000). Schiphol, The Netherlands/Schipol Group.

Figure 5c. Noise efficiency at Frankfurt airport. 1987-1999



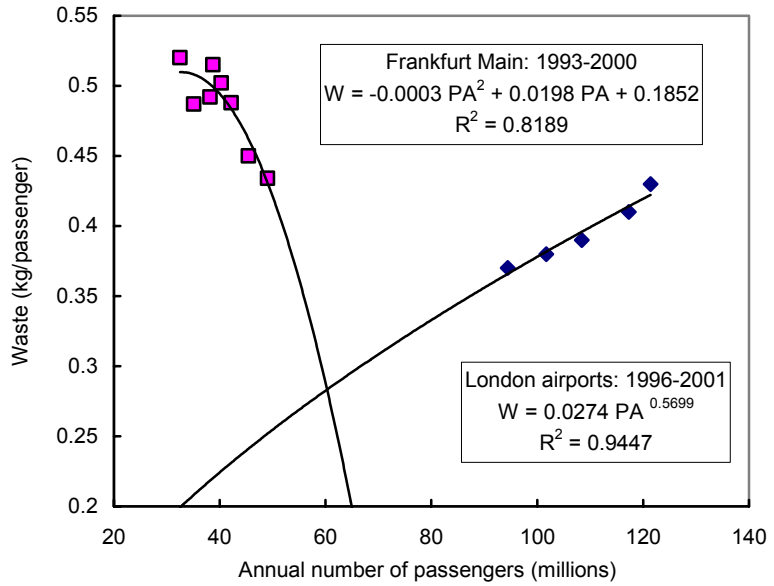
L_{eq} – area of land covered by the equivalent constant sound level
Data compiled from: *Frankfurt Airport: Environment—Noise Reduction.* (2001). Frankfurt, Germany, Fraport.

Figure 5d. Air pollution efficiency at Zurich airport, 1997-2000



Data compiled from: *Environmental Report 2000.* (2001). Zurich, Switzerland/Unique Environmental Services.

Figure 5e. Waste Efficiency at London airports, 1996-2001, and Frankfurt Main airport, 1993-2000



Data compiled from: *Waste Management.* (2001). London, UK/British Airport Authority; *Frankfurt Airport: Environment—Noise Reduction.* (2001). Frankfurt, Germany, Fraport.

ATC/ATM

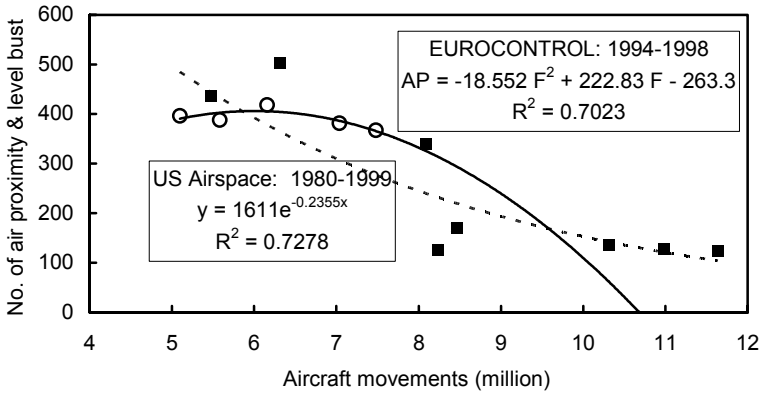
Figure 6 illustrates safety of the air traffic control system in terms of the number of air proximities and level busts in relation to the annual number of aircraft movements in the airspace of Europe and U.S. As can be seen, in both regions, this indicator generally decreased with increasing of the number of aircraft movements, but the rates of decrease are different. Nevertheless, both systems have developed in a sustainable way according to this indicator, that is, flying has been carried out with decreasing risk of the air proximities under conditions of increasing of the traffic density.

Airlines

Figure 7a illustrates punctuality of the ten major U.S. airlines. It is expressed as the proportion of the delayed ATMs in relation to the total number of ATMs carried out per year during the period 1988 to 1999. As can be seen, generally, the proportion of cancelled flights generally increased at an increased rate with increasing of the number of the number of ATMs,

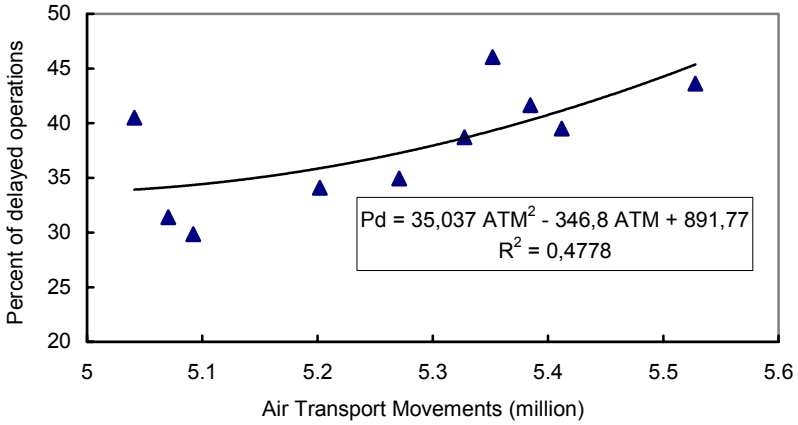
which implies lack of the system's sustainable development with respect to this indicator.

Figure 6. Safety in European airspace, 1994-1998, and U.S. airspace, 1980-1999



Data compiled from: *National Transport Statistics 2000.* (2001). Washington DC, USA/ U.S. Bureau of Transport Statistics, U.S. Bureau of Transportation; *The Future of Aviation: The Government's Consulting Document on Air Transport Policy.* (2000). London, UK/Department of the Environment, Transport and Regions; *The Creation of the Single European Sky.* (1999). Brussels, Belgium/European Commission.

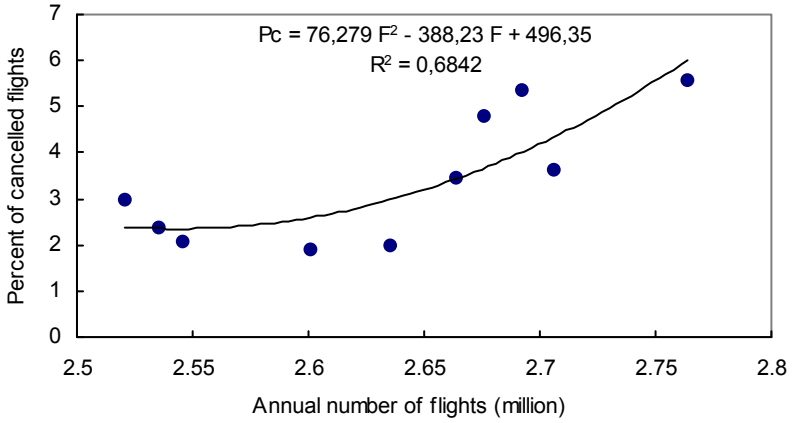
Figure 7a. Punctuality of ten major U.S. air carriers, 1988 – 1999



Data compiled from: *Major Airport Flight Delay.* (2001). Washington, DC, USA./ Office of Airline Information, U.S. Department of Transportation.

Figure 7b illustrates reliability of the ten U.S. major airlines in terms of the proportion of cancelled flights in relation to the total number of flights carried out per year. All reasons for cancellations, from bad weather to technical failures, are included. As can be seen, similar to punctuality, this proportion increased at an increasing rate with increasing of the total number of flights. Such relationship implies a lack of sustainability of the system development with respect to this indicator.

Figure 7b. Reliability of ten major U.S. air carriers, 1988–1999



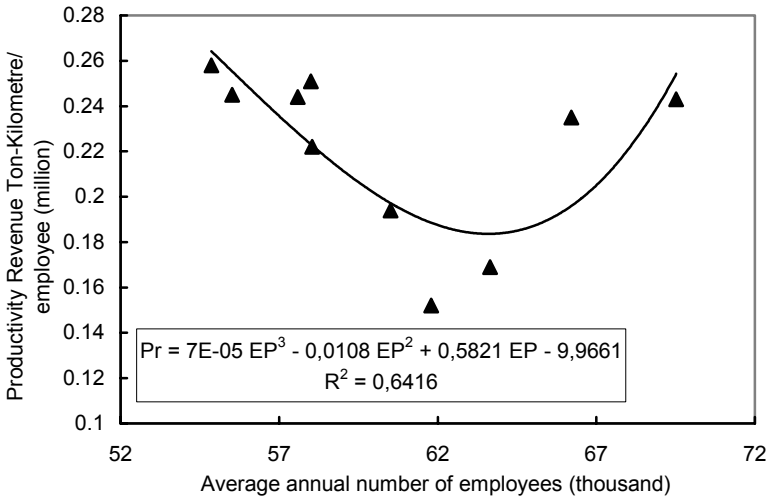
Data compiled from: *Major Airport Flight Delay*. (2001). Washington, DC, USA./ Office of Airline Information, U.S. Department of Transportation.

Figure 7c illustrates productivity at Lufthansa Group (Germany) expressed as RTK per employee in relation to the average annual number of employees. As can be seen, productivity decreased until the number of employees reached about 63 thousands but after that it increased despite that the number of employees continued to rise. This happened due to airline improvements; but the primary cause was the increase of long-haul intercontinental flights. Consequently, according to this indicator the group changed its long-term development trend from unsustainable to sustainable.

Figure 7d illustrates efficiency of fuel consumption at British Airways during the period 1974-2000. It is expressed in terms of grams of fuel consumed per RPK in relation to the total annual volume of RPK. As can be seen, this consumption generally decreased at a decreasing rate with increasing of the volume of RTK, which also meant decreasing of the associated air pollution. Such long-term sustainable development was undoubtedly achieved because the airline has permanently modernized its

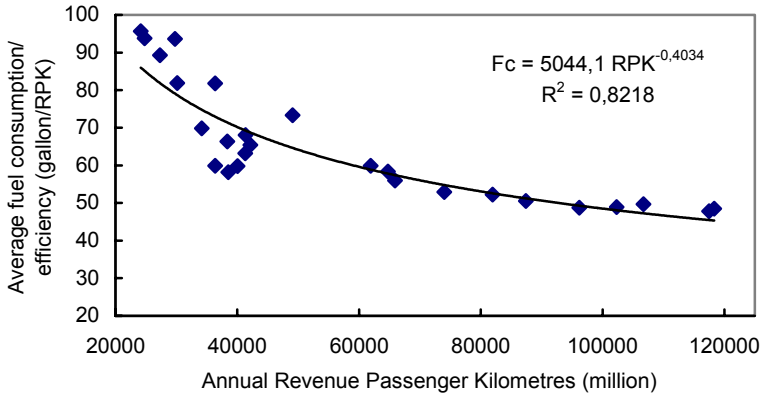
fleet and because it was provided with more effective services by ATM/ATC during operations over its air route network.

Figure 7c. Labour productivity of Lufthansa group, 1991-2000



Data compiled from: *Annual Report 2000: Ten-year Statistics.* (2000). Frankfurt, Germany, Lufthansa (2000).

Figure 7d. Fuel efficiency at British Airways, 1974-2000

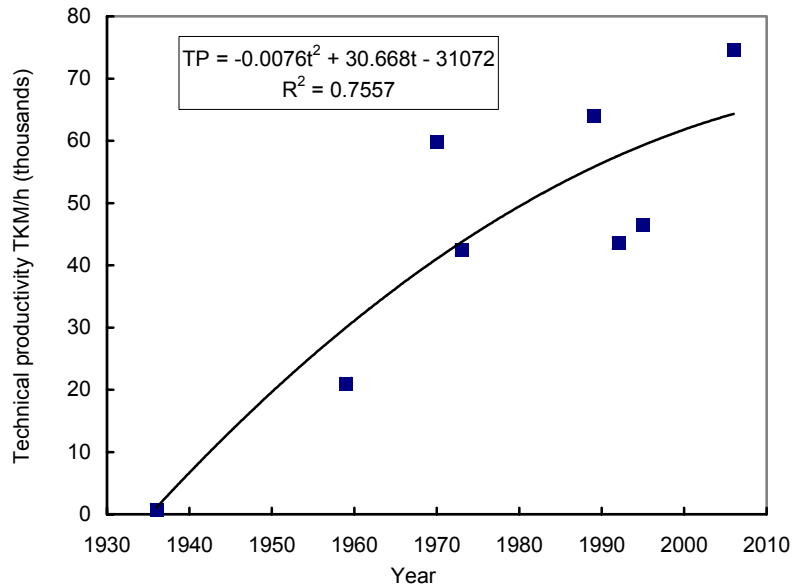


Data compiled from: *From the Ground Up: Social and Environmental Report 2001.* (2001). Wasterside, Middlesex, UK, BA.

Airspace Manufacturers

Figure 8a illustrates the main steps in progress in development of the aircraft technical productivity in terms of the number of TKM/hour. As can be seen, this productivity increased over time thanks to both airlines and their requirements as well as to capabilities of aerospace manufacturers. After introducing the aircraft Douglas DC 3, the rise of technical productivity was achieved by developing the larger aircraft, primarily, and by increasing of the aircraft operating (cruising) speed, secondarily. A culmination of development of this productivity will certainly be reached after introducing the aircraft Airbus A380. In addition, this included development and upgrading of engines in terms of their fuel and air pollution efficiency and sophisticated avionics. Consequently, the system has recorded long-term sustainable development.

Figure 8a. Aircraft technical productivity since the development of the plane DC3 to present

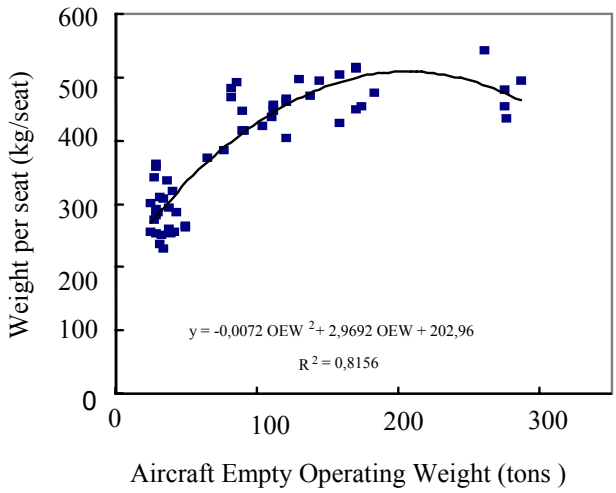


Data compiled from: "Commercial Aircraft Directory Part I, II." (2001). *Flight International Oct/Nov*; "Regional Aircraft: World Airlines: Part I." (2001). *Flight International, Sept.*

Figure 8b illustrates the use of different materials (resources) for manufacturing aircraft expressed by the average weight per seat. As can be seen, for contemporary aircraft, this weight increased at a decreasing rate

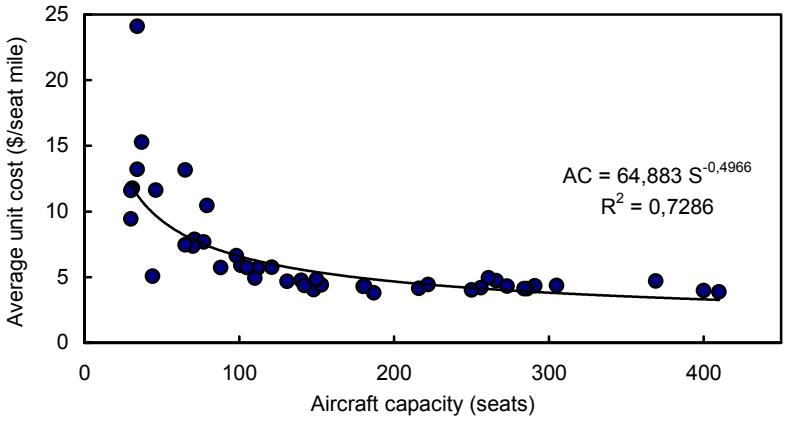
with increasing of the aircraft weight. This illustrates achievement of sustainable development with respect to increasing of the aircraft size, that is, for manufacturing larger aircraft less material is used per unit capacity (seat).

Figure 8b. Average weight per seat on aircraft compared to aircraft size



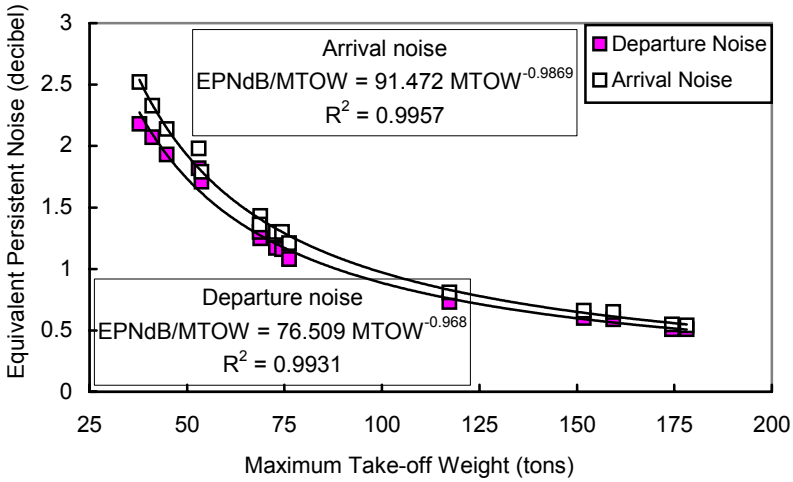
Data compiled from: "Commercial Aircraft Directory Part I, II." (2001). *Flight International Oct/Nov*; "Regional Aircraft: World Airlines: Part I." (2001). *Flight International, Sept.*

Figure 8c. Average cost per seat mile compared to potential number of seats



Data compiled from: *Economic Values for Evaluation of Federal Aviation Administration Investment and Regulatory Decisions.* (1998). Report FAA-APQ-98-8 U.S. Department of Transportation, Federal Aviation Administration, Washington DC, USA.

Figure 8d. Level of noise for aircraft per unit of aircraft's maximum take-off weight compared to its potential maximum take-off weight, for arrivals and departures



Data compiled from: "Commercial Aircraft Directory Part I, II." (2001). Flight International Oct/Nov; Environmental Impact of Air Transport in Comparison with Railways and Transport by Rail in the European Union. (1999). Madrid, Spain: Hera-Amalthea, S.L.; "Regional Aircraft: World Airlines: Part I." (2001). Flight International, Sept.

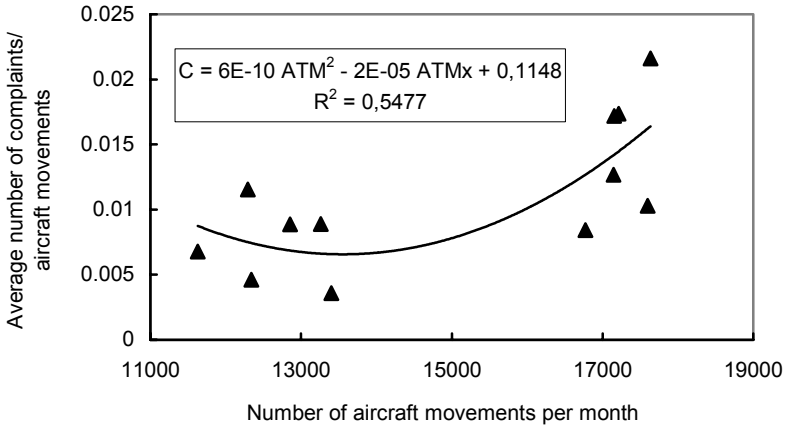
Figure 8c illustrates development of the aircraft efficiency in terms of the average cost per seat mile relative to the aircraft capacity (the number of seats). As can be seen, this cost decreased at a decreasing rate with increasing of the aircraft size thus indicating larger aircraft as being more efficient in relative terms. If development of bigger aircraft is an objective in terms of sustainability, then sustainability was achieved in the long term.

Figure 8d illustrates aircraft noise efficiency expressed as the level of noise in terms of Equivalent Persistent Noise in Decibels (EPNdB) per unit of the aircraft maximum take-off weight in relation to its weight. As can be seen, the relative level of noise decreased more than proportionally with increasing of the aircraft maximum take-off weight for both aircraft arrivals and departures. The arrival noise was slightly higher than the departure noise. Again, if development of bigger and relatively quieter aircraft is an objective, the progress has been sustainable with respect to this indicator.

Community Members

Figure 9 illustrates noise disturbance at Manchester Airport (UK) expressed by the average number of complaints per ATM in relation to the total number of ATMs carried out during the given period of time. As can be seen, when the average number of movements carried out per month is 13 thousand or less the average number of complaints decreased but when the average number of move increased the average number of complaints increased more than proportionally. This indicates that the airport has grown in an unsustainable way according to the attitudes of local population.

Figure 9. Average number of complaints per air traffic movement compared to total number of air traffic movements, Manchester Airport, 1998-1999



Data compiled from: *Manchester Airport Complaints and Community Disturbance Report: 1998-1999.* (1999). Machester, UK: Manchester Airport PLC.

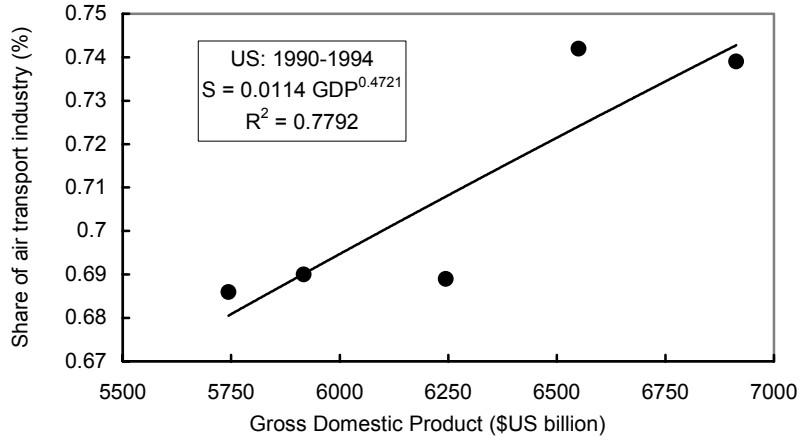
Governments

Figure 10a illustrates economic benefit obtained by the U.S air transport industry expressed by its share in the total GDP during the limited period 1990 to 1994. As can be seen, this share increased linearly with increasing of the national GDP, which indicates the industry's ability to permanently upgrade its contributions to the national economy (from 0.68% in 1990 to 0.74% in 1994 in the total GDP). Consequently, the industry developed in a sustainable way during the observed period with respect to this indicator.

Figure 10b illustrates an example of the contribution of the national air transport system to globalization and internalization of the UK trade sector during the period 1992 to 1998. As can be seen by the country's import and export, the share of air transport by value rose with increasing of the total

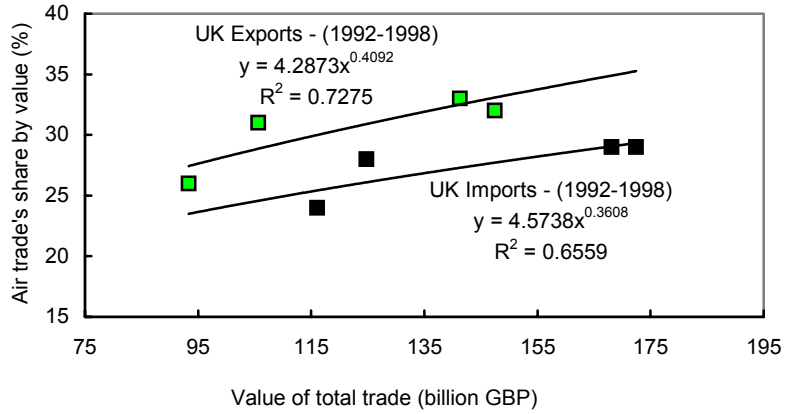
value of trade. This indicates the system's ability to gain more expensive shipments, which in turn indicates its sustainable development with respect to this indicator.

Figure 10a. Economic benefit of the U.S. air transport system, 1990-1994



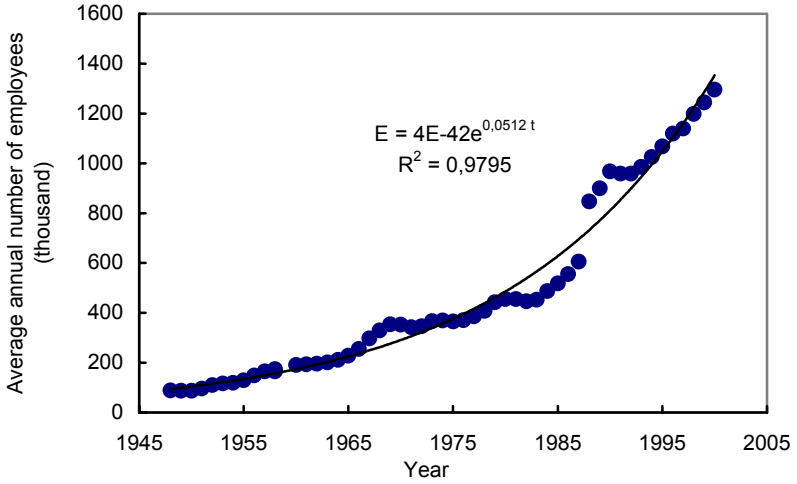
Data compiled from: Han, X. and Fang, B. (1998). "Measuring transportation in the U.S. economy" *Journal of Transportation and Statistics, 93-102.*

Figure 10b. Contribution of UK air transport system to the internalization and globalization of the UK trade sector, 1992-1998



Data compiled from: *UK Air Freight Study Report.* (2001). London UK: Department of the Environment, Transport and Regions.

Figure 10c. Overall number of persons employed by U.S. air transport industry, 1945-2001

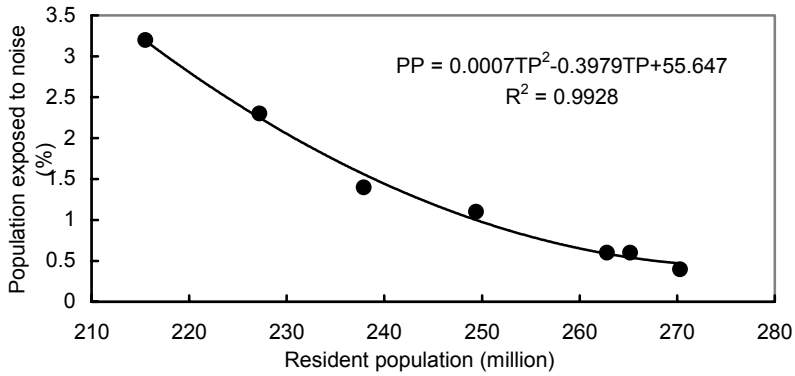


Data compiled from: *National Transport Statistics 2000.* (2001). Washington, D.C., USA: U.S. Bureau of Transport Statistics, U.S. Department of Transportation.

Figure 10c illustrates development of employment in the U.S. air transport industry during the period 1945 to 2001. As can be seen, the long-term growth of the number of employees was approximately exponential. It started from about one hundred thousand in 1945 and reached about one million four hundred thousand in 2001: a fourteen-times increase. There were variations around the general trend indicating restructuring of the sector after deregulation of the airline industry in 1978 and the global crisis before and after the Gulf War in 1991. Nevertheless, in the long term, according to this indicator, the system is developing in a sustainable way.

Figure 10d illustrates global noise efficiency at 250 U.S. main airports. This efficiency is expressed as the proportion of the population exposed to air transport noise in relation to the total resident population. As can be seen, during the period 1975 to 1998, this proportion decreased more than proportionally with increasing of population, from three percent to less than one-half percent. Certainly, such a long-term trend was achieved by improvements of airport and land use planning; resettlement of persons who previously lived closer to these airports; improvements of aircraft operational procedures; and modernization of aircraft fleet. Consequently, according to this indicator the system is developing in a sustainable way.

Figure 10d. Global noise efficiency around 250 largest U.S. airports, 1975-1998

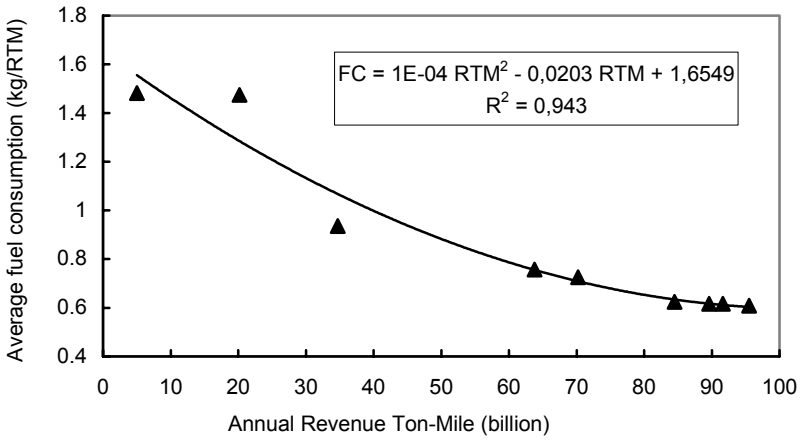


Data compiled from: *National Transport Statistics 2000.* (2001). Washington DC, USA: U.S. Bureau of Transport Statistics, U.S. Department of Transportation.

Figure 10e illustrates global energy efficiency of the U.S. airline industry expressed by the average fuel consumption per RTM in relation to the total annual amount of RTMs. As can be seen, this consumption decreased more than proportionally with increasing of the total amount of RTMs, from about 1.6 kilograms/RTM to just about 0.6 kilograms/RTM (approximately 2.7 times). At the same time the annual amount of RTMs increased about five times. The main influencing factors were improvements in the aircraft design and fleet use. Consequently, with respect to this indicator, the system developed in a sustainable way during the observed period.

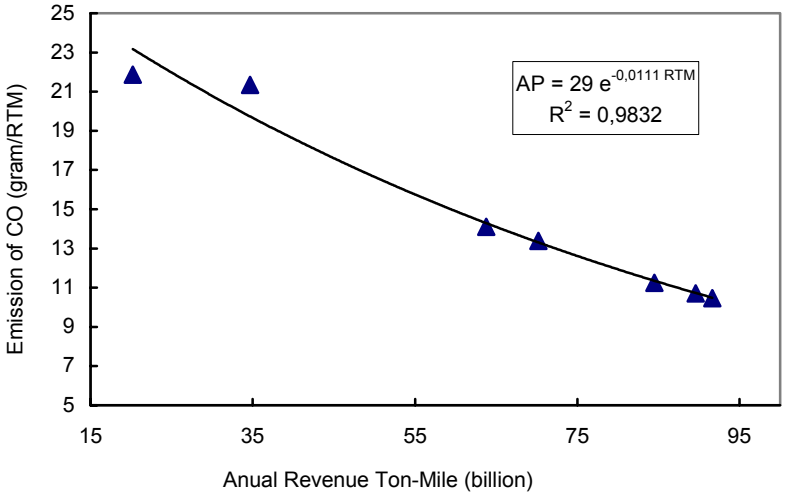
Figure 10f illustrates global air pollution efficiency of the U.S. airline industry. Similar to the fuel consumption case, this efficiency is expressed by the quantity of Carbon Oxide (CO) emitted per RTM in relation to the annual amount of RTMs carried out during the period 1970 to 1998. As can be seen, more than a proportional decrease of this emission, from about 22 grams/RTM to about 10 grams/RTM with increasing of RTMs from about 16 to about 95 billion RTMs per annum, took place. The reasons are the same as in the case of fuel consumption and include improvements of aircraft engines in terms of the quality of burning fuel. Consequently, according to this indicator, the system developed in a sustainable way.

Figure 10e. Global energy efficiency of the U.S. airline industry, 1960-1999



Data compiled from: National Transport Statistics 2000. (2001). Washington DC, USA: U.S. Bureau of Transport Statistics, U.S. Department of Transportation.

Figure 10f. Global air pollution efficiency of the U.S. airline industry, 1970-1998



Data compiled from: *National Transport Statistics 2000.* (2001). Washington DC, USA: U.S. Bureau of Transport Statistics, U.S. Department of Transportation.

CONCLUSIONS

The paper explains the methodology for assessment of the sustainability of an air transport system and its potential application. The methodology consists of an indicator system consisting of individual indicators and their measures. They represent the system's operational, economic, social and environmental performance. The particular indicators and their measures are defined in terms of the system's positive effects and negative impacts and in relation to the system's output, in both monetary and non-monetary terms. Their relevance for different actors such as users (air travellers), air transport operators, aerospace manufacturers, local communities, governmental authorities at different scales (local, national, international), international air transport associations, pressure groups and the public are also included. In total, fifty-eight individual indicators and their sixty-eight measures are defined.

The application of the methodology includes estimation of twenty-six indicators. Due to the structure of the particular indicators and availability of the relevant data, almost all cases relate to the U.S. air transport industry while just a few ones relate to the European air transport industry. The results show (and confirm) that the long-term development of the air transport system and its particular components are sustainable with respect to most indicators of the economic, social and environmental dimension of performance from the aspects of most actors involved. Nevertheless, there are still some doubts about unsustainable indicators of the operational dimension of performance such as punctuality and reliability of service at airports and airlines; indicators of the environmental dimension of performance such as air pollution, waste efficiency and noise disturbance at airports; and indicators of the economic dimension of performance such as labour productivity of airlines.

Generally, based on the analysed cases, it can be said that the air transport system, with few exceptions, has shown sustainable development under given circumstances and during observed period. Stable sustainable trends have been established. However, after 9/11, the operational and economic dimension of performance have become of growing importance illustrating the system and its components' struggle for survival. Questions about the system's future sustainable development as well as its sustainability compared with the sustainability of other transport modes and other sectors of the national and international economy, using the same or modified methodology, still need to be addressed.

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MODELING THE EFFECT OF ENLARGED SEATING ROOM ON PASSENGER PREFERENCES OF DOMESTIC AIRLINES IN TAIWAN

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ABSTRACT

This study focuses on measuring the effect on Taiwanese airlines if they were to enlarge the seating room in airplanes per passengers' preferences. A stated choice experiment is used to incorporate passengers' trade-offs regarding preferred measurements; furthermore, a binary logit model is used to model the choice behavior of airline passengers. The findings show that the type of seat is a major significant variable; price and the airline company are also significant. The conclusion is that airlines should put more emphasis on the issue of improving the quality of seating comfort.

INTRODUCTION

After the deregulation of the airline industry, and due to the expectations of an increased demand, most airlines placed as many seats as possible in each plane. As a result, the seating space for each passenger, including legroom and arm rest room, had to be sacrificed. Consequently, airlines offer poor service when it comes to standards of seating comfort. Airline travelers are becoming more and more concerned about the quality of seating comfort during their journey in the sky, especially during long-haul inter-continental trips.

Based on the results of some reports, the majority of airline passengers consider the legroom, armrest, and personal seating room of their seat to be

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quite important. Business travelers especially viewed the quality of seating room as a critical index in the level of total service of an airline (Toynbee, 1994; Flint, 1995). Alamdari (1999) indicated that airline passengers considered the quality of seating room to be one of the important factors when selecting an airline. Fiorino (1999) stated that the uncomfortable seating configuration in coach class is the root of much passenger discontent. Hence, there are more and more airlines, including United Airlines, American Airlines, British Airways, Virgin, and Singapore Airlines, that are directing a lot of effort into reconfiguring seating and expanding legroom so that they can provide better seating comfort to their passengers (McDougall, 2002).

In Taiwan, some local researches have shown that the quality of seating room is one of the most important factors when travelers select a domestic airline. However, the quality of seat comfort those airline passengers actually receive falls far short of their expectations. It is evident that if an airline would pay more attention to improving seat comfort, the passengers might attach a higher value of total service quality to that airline, and this could very well change their preferences. In other words, the effect of seating environment on a passenger's choice of airline should not be ignored.

In addition, because of the gradual decline in the passenger load factor in recent years and the upcoming competition of high speed rail in Taiwan, it appears the time has come to seriously discuss the policy of passenger-maximization. If airlines are willing to adjust their cabin configuration and decrease the total number of seats, or rather enlarge the seating space of each seat in economy class, they can promote different price strategies and most likely raise their load factor as well as their revenue.

The aim of this study is to explore the change in airline passengers' preferences in situations where service quality (in terms of seating room) has improved by offering an enlarged seat size. It should be noted that, in this study, enlarged seats do not mean increasing the number of business class seats. Enlarged seating capacity could simply mean that the size of the economy class seats is enlarged. The stated choice method (Louviere, Hensher & Swait, 2000) is used to administer an experimental design that includes three variables: seat type, price, and company (airline). Then a binary logit model is used to describe the choice behavior of airline passengers. Though this paper focuses on Taiwan's domestic airline passengers market, the results can also be applied to the marketing practice of international airlines. This is especially true for those domestic airlines in Taiwan that are well prepared to service future routes between Taiwan and Mainland China. The results of this study could provide some suggestions for improvement in passenger service.

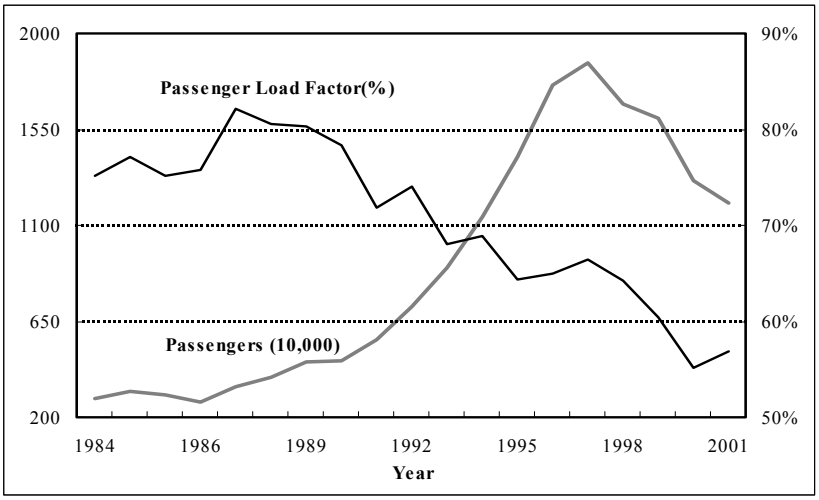
BACKGROUND

Taiwan's Domestic Airline Passenger Market

The airline industry in Taiwan has grown rapidly over the past two decades, especially after its deregulation in 1988. Air transportation in Taiwan services about two percent of intercity traffic. The round trip between Taipei in the north, the political and economical center of Taiwan, and Kaohsiung, the largest metropolitan city of southern Taiwan, is the main element of the domestic airline transportation. In 2001, there were almost four million passengers, 33 percent of Taiwan's domestic air transportation traffic, between Taipei and Kaohsiung.

However, in recent years, due to a combination of drastic expansion of the airline industry, and a slow but steady decline in the economy, the passenger load factor has gradually declined. In 2001, the passenger load factor was only about 56 percent. This trend is illustrated in Figure 1.

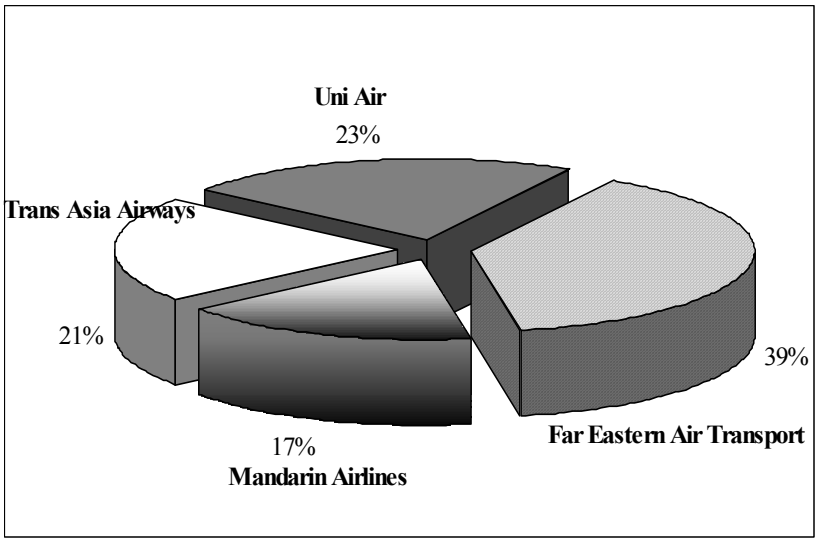
Figure 1. The growth trend of Taiwan's airline passengers market, 1984-2001.



Source: The Statistic Year Book of Civil Aviation, Civil Aeronautics Administration (C.A.A.), 2002.

At present, there are four domestic airlines in Taiwan: Far Eastern Air Transport, Trans Asia Airways, Uni Air, and Mandarin Airlines. Their individual market share of the Taipei-to-Kaohsiung route is shown in Figure 2. The figure shows that Far Eastern Air Transport dominates the air passengers market on this route, with Trans Asia Airways and Uni Air following behind.

Figure 2. Market share for the Taipei-to-Kaohsiung route, among the four domestic airlines in Taiwan, 2001.



Source: Civil Aeronautics Administration. (2002). The Statistic Year Book of Civil Aviation.

These four domestic airlines provide two classes of cabin configuration: business class and economy class. However, the number of total seats on business class is no more than 12 (only about five percent of total number of seats on each plane). This means that only 12 passengers can actually sit in business class on each flight, some times even less. Thus nearly 95 percent of airline passengers have no choice but to sit in the very crowded economy class seats.

In addition, these business class seats are frequently used as rewards for frequent flyers, and generally speaking, the load factor of business class seats is higher than that of the economy class seats. Consequently the revenue from business class seats does not do much to help air carriers increase their profit margin. If airlines would rearrange the seating layout in their airplanes, that is to say, if they would increase the number of business class seats or enlarge most, if not all, of the economy class seats, they would improve the service quality by increasing seat comfort, as well as indirectly increasing their load factor and consequently their revenues.

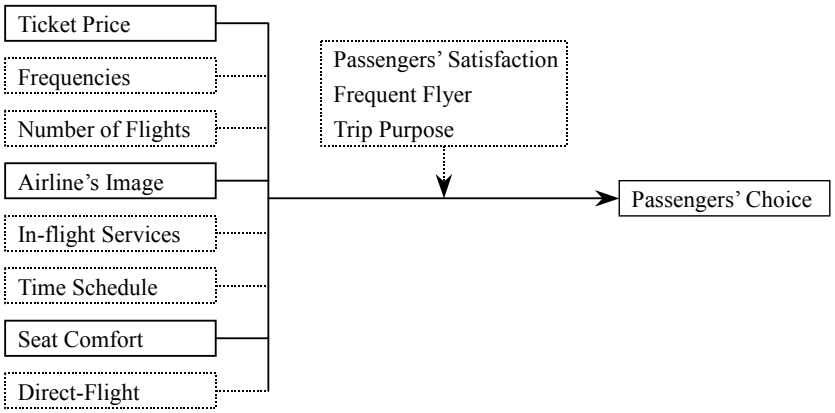
It is evident that Taiwan's domestic airline passengers market is shrinking, and a new marketing strategy is required to induce latent demand. Meanwhile, several studies have indicated that service quality, in terms of cabin seating, is a fairly important factor when airline passengers select an airline. As a result, providing better seating by increasing the length and

width of the seating space should be given high priority. We suggest that the policy of enlarging the seating room could be a new marketing strategy, and its effect on airline passengers' preference of airlines should be further analyzed.

STATED CHOICE EXPERIMENT

There are many factors that affect passengers' choice of airlines, including time schedule, number of flights, frequency, number of direct-flights, airlines' image, punctuality, in-flight services, seat comfort, passengers' attitudes, passengers' purpose for their trip, and passengers' satisfaction with the airlines. (Proussaloglou and Koppelman, 1995; Ghobrial, 1989; Ippolito, 1981). A conceptual framework, as shown in Figure 3, can describe the passengers' choice behavior. However, the effects of seat comfort and the image of the airline are rarely quantified. Hence, the relationships that are presented as solid lines in Figure 3 are the primary concern of this study. Because it is not easy to get the revealed preference data of the effects of these variables on passengers' choice, especially the effect of seat comfort, a stated choice experiment is used to present and analyze the quantified effects of those variables.

Figure 3. The conceptual framework of passengers' choice of airline



We selected three attributes for constructing the stated choice experiment. The attributes and associated levels are defined in Table 1.

Table 1. Three attributes and associated levels of the stated choice experiment of factors that affect passengers' choice of airline

Variables	Levels
Seat-Type	(1) 100 percent of the seats are the same as market practice (2) 50 percent of the total seats are enlarged seats (3) 100 percent of the total seats are enlarged seats
Price	(1) Market average (2) 10 percent higher than market average
Brand	(1) Far Eastern Air Transport (FAT) (2) Trans Asia Airways (TNA) (3) Uni Air (UNI). (4) Mandarin Airlines (MAL)

The first attribute is the type of seat, which has three levels: 100 percent of the seats on each flight are the same size as market practice, 50 percent of the seats on each flight are enlarged seats (and 50 percent of the seats are standard economy class seats), and 100 percent of the seats on each flight are enlarged seats. The second attribute is ticket price with two levels: same as market average and 10 percent higher than market average. The last attribute is the company name of the airline corresponding to the four airlines in the domestic airline passengers market in Taiwan: Far Eastern Air Transport (FAT), Trans Asia Airways (TNA), Uni Air (UNI), and Mandarin Airlines (MAL).

We viewed the airline that passengers took as a fixed alternative. So the first level of seat type (100 percent seats are the same size as market practice) was eliminated from the experiment. As a result the stated choice experiment contained 16 profiles that were generated from the experimental design of 2 X 2 X 4. The respondents had to finish three choice tasks. The first and second choice tasks asked respondents to choose an airline from the choice set that included two airline alternatives, respectively. One was the airline that the respondents took, and the other was the profile that was selected randomly, without duplication, from the 16 possible profiles. The third choice task asked respondents to choose from the two profiles that were presented separately in the first choice task and the second choice task. That is to say, all respondents faced two alternatives on each choice task.

The main interest of this form of choice game, especially the first two choice tasks in the choice game, was to ask passengers to compare their original choice of airline (with crowded and narrow seats) with the simulated airline (with enlarged seats). This way we could find out the different choice behaviors of passengers in the situation of improved seat comfort. The

choice game experiment was conducted in a questionnaire. Respondents were randomly selected from the air flight route of Kaohsiung-to-Taipei. In addition to the choice game, socio-economic status and demographic information were gathered for sample descriptive and further analyses.

Locally hired and trained interviewers were assigned to Kaohsiung Airport to interview randomly selected passengers who were going to Taipei. Passengers were interviewed while they were waiting for their flight and asked to participate in a survey; 192 passengers fully completed the survey.

EMPRICAL RESULTS AND DISCUSSION

In this section, we first describe the composition of samples and then analyze the results of the passengers' choice behavior. We constructed a passengers' choice model using the binary logit model. In addition, some conclusions as to the results are drawn here.

Sample Description

The 192 respondents consisted of 60 percent male, and 40 percent female. Most respondents were aged 21 to 30 (51%); followed by those aged 31 to 40 and 41 to 50. In addition, about 70 percent of all respondents were college or graduate school graduates. Furthermore, almost 30 percent of the respondents were business trip passengers and 70 percent were non-business trip passengers.

Respondents were asked what class of seat they were taking. The results showed that 88 percent of all respondents were taking economy class seats and 12 percent were taking business class seats. This indicates that the load factor of business class seats is higher than for the economy class seats. Meanwhile, only half of the business class passengers (that is, six percent of all respondents) paid full price.

Furthermore, over 85 percent of the respondents were unhappy with the seating situation currently provided on domestic flights. The major factors leading to their dissatisfaction were nothing more than lack of stretching out space, restrained armrest room, and the feeling of oppression caused by the lower overhead compartments. At the same time, nearly 90 percent of the respondents would prefer an airline with larger and more comfortable seating configuration if their travel time would be double of what it was now.

Factors Affecting the Passengers' Choice of Airlines

After we referenced several studies related to passengers' choice of airline, we listed 10 possible factors affecting the choice behavior. Respondents were asked to rank the first three of these factors using the numbers 1, 2, and 3 to represent "very important," "important," and "less important", respectively. A score of three was assigned to the factor ranked

"very important," a score of two assigned to the factor ranked "important," and a score of one assigned to the factor ranked "less important." The rest of the seven affecting factors that respondents did not have to rank were assigned a score of zero. As a result, the total score of each affecting factor can be calculated.

$$SQ_1 = \sum_{j=1}^{N} SQ_4 \tag{1}$$

In Equation 1, SQ_1 is the total score of affecting factor *i*, and SQ_4 is the score of affecting factor *i* that was given by respondent *j* (total number of respondents are *N*). The value of SQ_4 could be 3, 2, 1 or 0. Thus we know that the higher the value of factor *i*(SQ1), the more important factor *i* is. Thus we can rank the importance of these affecting factors according to each factor's total score value. Table 2 shows the results of ranking the affecting factors according to importance.

Table 2. Importance of affecting factors on passengers' choice decision.

Affecting Factors	Importance Ranking		
	Total	Business Passengers	Non-Business Passengers
Schedule of Time Table	1	2	1
Safety	2	1	2
Ticket Price	3	4	3
Seat Comfort	4	3	6
Airlines' Image	5	5	5
Punctuality	6	9	4
In-Flight Service	7	10	7
Frequent Flyer Member	8	8	8
Reservation & Check-in Service	9	7	9
Aircraft Type	10	6	10

From the results shown in Table 2, it is clear that the top two factors affecting passengers' choice of airline are "schedule of the time table" and "safety." The factor of "seat comfort" is ranked fourth by the total number of passengers. Hence, we can say that most passengers seem to give more consideration to the quality of seat comfort than to other affecting factors when they select an airline. Therefore, if air carriers are willing to make more improvements in terms of seating space on their fleet, it might very likely bring some positive benefits in terms of passengers' choice.

Moreover, it also can be seen that the importance ranking of some affecting factors is quite different between business passengers and non-business passengers. For example, the factor of "seat comfort" is ranked third for business passengers, and sixth for non-business passengers. This means that business passengers view the effect of seat comfort on their choice decision as more important than non-business passengers. Also, the factor of "in-flight service" is ranked the last (tenth) for business passengers, and seventh for non-business passengers. This implies that business passengers, due to their characteristics of frequent flying, are not interested in the quality of in-flight service very much. Contrary, business passengers pay more emphasis on "reservation and check-in service" and "aircraft type" than non-business passengers. But the factor of "punctuality" is ranked ninth for business passengers and fourth for non-business passengers. This result is contrary to the expectations that business passengers would put more emphasis on the importance of "punctuality." One possible reason for this may be that business passengers may mostly be frequent flyers and as such are familiar with flight schedule information and realize that the quality of punctuality is actually quite good for market practice.

Analysis of Passengers Satisfaction

The analysis of passengers' satisfaction can tell us the quality of airline services that passengers actually received. Ten service factors were selected and respondents were asked to separately evaluate their satisfaction with these service factors that they received using a five-point scale: "very good," "good," "moderate," "bad," and "very bad." Next, five different scores were assigned, from a maximum of five to a minimum of one, to represent the five-point scale sequentially. The scores of each service factor was calculated. The results are shown in Table 3.

The ten service factors presented in Table 3 are slightly different from the ten affecting factors presented in Table 2. "Frequent Flyer Member" and "airlines' image" are deleted from the set of affecting factors, and the service factor of "responsible for complaints" is added. The affecting factor of "in-flight service" is divided into two: "flight attendant service" and "in-flight catering service."

A study of the results of Table 3 shows that the service factor of "seat comfort" is ranked far behind the other eight service factors. Also, its mean score is 2.86, indicating that the service quality that passengers received was below average. Compared to the results of Table 2, it is obvious there is a service gap between passengers' expectation and what is received. Again, it can be seen that the improvement of the quality of seat comfort should be advanced to the most important place. This will result in positive effects in terms of passengers' satisfaction.

Table 3. Ranking of passengers' satisfaction with service factors received

Service Factors	Ranking	Mean Score*	Standard deviation
Reservation and Check-in Service	1	3.67	0.61
Flight Attendant Service	2	3.57	0.69
Safety	3	3.39	0.77
Punctuality	4	3.27	0.74
Responsible for Complaints	5	3.24	0.57
Schedule of Time Table	6	3.21	0.68
Aircraft Type	7	3.12	0.62
Ticket Price	8	2.90	0.74

* 5 = very good; 4 = good; 3 = moderate; 2 = bad; 1 = very bad

The standard deviation shown on Table 3 may look high compared to the sample size of our study (192 respondents) but after checking several local reports related to customers' satisfaction analysis and airlines service quality evaluation we found our results were reasonable compared to these local reports.

In addition, each score of service factors per airline was summarized to obtain the total score of passengers' satisfaction with each airlines. Each airline had 48 respondents. The rankings of passengers' satisfaction of Taiwan's domestic four airlines are presented in Table 4.

Table 4. Ranking of passengers' satisfaction with the four domestics airlines in Taiwan, based on passengers' satisfaction scores of 10 service factors

Airline	*Ranking*
Trans Asia Airways (TNA)	1
Far Eastern Air Transport (FAT)	2
Uni Air (UNI)	3
Mandarin Airlines (MAL)	4

The results of Table 4 suggest that Trans Asia Airways (TNA) is the first ranked, implying that most passengers are satisfied with the services offered by TNA. The second ranked airline is Far Eastern Air Transport (FAT). This result seems to be contrary to their market share: FAT dominates the air passengers market with Trans Asia Airways and Uni Air following behind. One may infer that the timetable schedule of FAT is more convenient than other air carriers and that the result relates more to the final choice of the passengers. However, the services provided by TNA, nevertheless received the highest score.

Choice Model

In order to quantify the effects of improving seat comfort on passengers' preference of an airline, a binary logit model is used to construct a passengers' choice model. The variables that were taken into account are shown in Table 5.

Table 5. Variables used to construct a passengers' choice model

Variables	Definition
Price	Dummy variable. If ticket price is 10 percent higher than market average, the value of it is 1; otherwise it is 0.
Seat_Type 1	Dummy variable. If the seat-size is a 50 percent enlarged seat, the value of it is 1; otherwise it is 0.
Seat_Type 2	Dummy variable. If the seat-size is a 100 percent enlarged seat, the value of it is 1; otherwise it is 0.
FAT	Dummy variable. If the company name of the airline is Far Eastern Air Transport, the value of it is 1; otherwise it is 0.
TNA	Dummy variable. If the company name of the airline is Trans Asia Airways, the value of it is 1; otherwise it is 0.
UNI	Dummy variable. If the company name of the airline is Uni Air, the value of it is 1; otherwise it is 0.

In this study, we only take into consideration the variables that show in the stated choice experiment of choice model estimation. All variables used in the model are dummy variables. The value of the "price" dummy variable is 1 if the price is 10 percent higher than market average price and 0 if the price is the same as market average price (reference level). There are two types of seat dummy variables. The value of the "seat-type 1" variable is 1 if 50 percent of the seats on the flight are enlarged seats and 0 if that is no the case. The value of the "seat-type 2" variable is 1 if the 100 percent of the seats on the flight are enlarged seats and 0 if that is not the case (the reference level is the same as in market practice). Finally, the company names of the airlines are set as three distinct dummy variables: "TNA" represents Trans Asia Airways, "FAT" represents Far Eastern Air Transport, and "UNI" represents Uni Air (the reference level is Mandarin Airlines). The results of this choice model are shown in Table 6.

The results in Table 6 signal that all variables are quite significant, although the variable of "seat_type 1" and "UNI" was less significant. At the same time, the probability of coincidence prediction is around 65 percent and

the index of goodness-of-fit is 0.11. This means that the performance of our model is moderately good.

Table 6. Estimated results of passengers' choice model of airlines

Variables	***Coefficients***	***t-value***
Constant	0.270	1.271
Price—Market average price	Reference Level	
Price—10% higher than market average price	-0.949	-6.930
Seat_Type 0	Reference Level	
Seat_Type 1	0.234	1.147
Seat_Type 2	0.508	1.784
FAT	0.535	2.884
TNA	0.681	3.447
UNI	0.203	1.054
MAL	Reference Level	
Samples	576	
Log Likelihood at Convergence	-356.684	
Likelihood Ratio (p^2)	0.11	

The sign of "price" is negative implying that passengers prefer the airline with the lower ticket fare to that with the higher ticket fare. This is identical with normal expectation. The sign of "seat_type 1" and "seat_type 2" are positive indicating that there are positive effects of enlarged seats on passengers' choice of airline. This result supports earlier inferences: passengers actually view seat comfort as an important factor in their choice decision. In addition, it is noted that the coefficient of "seat_type 1" is smaller than that of "seat_type 2." This means that the effect of 100 percent enlarged seats on passengers' choice is greater than that of the 50 percent enlarged seats. Furthermore, a *t*-test could be used to test if the null hypothesis that these two coefficients are equal is accepted.

$$t = \frac{\beta_2 - \beta_1}{\sqrt{Var(\beta_1) + Var(\beta_2) - 2Cov(\beta_1, \beta_2)}} \tag{2}$$

In Equation 2, $ß_2$ means the coefficient value of "seat_type 2," and $ß_1$ represents the coefficient value of "seat_type 1." According to this equation, the *t*-value is 1.69. This is significant compared to the critical value of 1.645 ($\propto$ = 0.1). This result implies that there is a slightly significant difference between the effects of 100 percent enlarged seats and 50 percent enlarged seats on passengers' choice of airlines.

We know that there were many travelers that rarely benefit from the service of business class seats. But, from the magnitude of the "seat_type 1" and "seat_type 2" coefficients, it is shown that if air carriers can improve seat comfort through enlarging the passenger seats (even if it is not to the extent of a business class seat), and even if only 50 percent of the total seats are enlarged, passengers will show a positive preference to this type of seat and the airlines that offer them.

Finally, the variable of "company name" is significant as well. Here, we can view "company name" variable as a proxy variable of the perception by the passengers of service quality of each airline. It supposes that the higher the satisfaction a passenger receives, the higher the coefficient value of "company name." The finding of Table 6 indicates that "TNA" has the greatest coefficient value. The second and third values of coefficients are "FAT" and "UNI." This implies that passengers who selected TNA would have stronger preferences toward TNA than passengers who selected FAT and UNI. The magnitudes of the "company name" coefficients are in agreement with the passengers' satisfaction with airlines as illustrated in the previous section.

CONCLUSION

In this research the effect of enlarged seats on passengers' preferences of airline was measured. It has been shown that enlarged seats do affect the choice decision of airline passengers. These findings indicate that airline passengers prefer airlines that have the largest seats and air carriers should seriously take the seat size and the issue of possible seat rearrangement into consideration.

In addition, ticket price is also a significant affecting variable although most studies, such as Ghobrial (1989), Ippolito (1981), and Yoo and Ashford (1996), indicate that ticket price may not play a significant role in air passengers' choice because there is not much difference in the ticket price between airlines. However, the stated choice experiment was used to show the possible varieties of ticket price, and found that a 10 percent price difference could affect passengers' choice significantly; nevertheless, the cross effects between seat-type and ticket price is not considered here. Generally speaking, airline passengers who pay a higher ticket price should receive a higher quality of seat comfort. That is to say, there is a small positive relationship between seat-type and price. In this study, it is supposed that any relationship between seat-type and price does not exist. Therefore, there is no analysis of the cross effect between enlarged seats and ticket price. This should be taken into consideration in a future study.

Finally, the variable of "company name" was used to measure the effect of passengers' satisfaction with a specific airline on choice decision. The

findings imply that there is a positive relationship between passengers' satisfaction with a specific airline and choice decision. In other words, the higher the satisfaction passengers receive from a specific airline, the higher the probability that those passengers choose that airline again. Hence, it also can be used to measure the passengers' loyalty to a specific airline.

Even though the study focuses on passengers in Taiwan, the findings of this study could also be applied to the international airline passengers market. It has been found that there are several international airlines that are gradually improving the seat comfort in their airplanes. The usual way of upgrading the quality of seat comfort is by enlarging the seating room. From this study, it can be concluded that enlarged seats could be an efficient marketing strategy.

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DEVELOPING A FLEET STANDARDIZATION INDEX FOR AIRLINE PRICING

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ABSTRACT

Quantifying subjective aspects is a difficult task that requires a great dedication of time from researchers and analysts. Nevertheless, one of the main objectives of it is to pave the way for a better understanding of the focused aspects. Fleet standardization is one of the subjective aspects that is extremely difficult to turn into numbers. It is of great importance to understand the benefits that may come from a higher level of standardization for airlines. A more standardized fleet may represent lower costs of operations and maintenance plus a much better planning of routes and flights.

Author's Notes: This study presents the first step on developing an index that would allow senior airline planners to compare different fleets and also simulate some results from maintaining or renewing their fleets. The index is herein called the Fleet Standardization or IPF (for the initials in Portuguese of Indice de Padronizacao de Frotas). Although being a preliminary study, the results obtained may already be tested to compare different fleets (different airlines) and also analyze some possible impacts of a fleet renewal before it takes place. Therefore, the main objective of this paper is to introduce the proposed IPF index and to demonstrate that it is inversely proportional to the number of different airplane models, engines and other equipment, such as avionics.

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INTRODUCTION

The need for standardization of the various items, equipment and characteristics of the aircraft composing an airline's fleet is a much discussed issue among aviation specialists and also among economists involved with the aviation industry. Few studies have been done (or publicized) on this subject, leaving the particularities of fleet standardization covered in a mist of several complex issues that are poorly explored in the conventional literature.

In view of this, the primary objective of this paper is to start a broad analytical study and stimulate further follow-on studies on airlines' fleet standardization (fleet commonality issues), while considering the factors that influence this standardization and the benefits that can be granted from a higher level of it. For this, an initial effort is made to quantify the level of standardization of a given airline fleet, bringing both study and discussion from a subjective to an objective point of view.

Due to the somewhat pioneering characteristics found in the present study, the authors acknowledge that errors may occur during the conception and development of the formulations and assumptions herein made. For this, the authors welcome any contribution, suggestion and criticism made on the purpose of continuing and improving the present study, since the primary goal is to contribute directly in the analysis and understanding of the challenging, complex and dynamic world of strategic airline planning.

FLEET STANDARDIZATION–DEFINITIONS AND INITIAL CONSIDERATIONS

When mentioning fleet standardization, the first common thought points to a fleet composed of the same type of aircraft (i.e., from the same manufacturer and the very same model/variant) painted in the same color scheme and aligned on the apron, just as seen in several airline ads. Through this common view, having an Embraer ERJ-145 and an Airbus A319 in the same fleet means a great loss of standardization, mainly due to the different manufacturer. Nevertheless, when going deeper into the term of fleet standardization, one should overcome the simple view of considering basic aircraft characteristics and incorporate engines, avionics, equipment, propellers, tooling and much more in his or her analysis.

This means that having several aircraft from different manufacturers or from a single manufacturer but of different variants may not indicate a lack of standardization, as long as these aircraft share some common characteristic or characteristics, for instance, the same engine manufacturer. As an example, four different Boeing airplanes (i.e., 737-700, 747-400, 767-300 and 777-200) can be equipped with powerplants from a single manufacturer, even if the engines themselves are different. Moreover,

engines of the same family (using the same engine core) can be installed in various types of aircraft, from different manufacturers. An example is the Pratt & Whitney of Canada PT-6, used in the Cessna Caravan/Grand Caravan, the Embraer Bandeirante and the Bombardier (de Havilland) Twin Otter, just to mention a few.

In order to understand correctly the technical consideration of airline fleet standardization, we shall refer to the basics parts of an airplane.

Aircraft Parts and Components

When asking a child about what an airplane is, the answer would probably be somewhere near "an airplane is a big vehicle that flies and has wings." Complementarily, aviation enthusiasts would try to better distinguish the different parts of an airplane in their response on the same question, stating that an airplane is made of wings, fuselage and engines. But for the purpose of this study we shall refer to the classification used for project and maintenance as the most appropriate means in describing an airplane, pointing that it is composed of a cell, an engine-propeller system (the powerplant), avionics and other equipment.

The *cell* is what we could refer as being the hull of the aircraft, meaning all structures, the hull itself and assorted mechanical parts. It is important to notice that in this group, we will not include any interior-related item such as seats, bins, galleys, etc. The cell alone does not fly, but it is responsible for lift forces generation.

It is very common to consider the engine-propeller group and the engine alone the same item. In fact this error occurs due to the variety of jet aircraft used nowadays, where the propeller simply does not exist or does not make itself apparent. When mentioning the engine-propeller group, it will only make sense for turboprop or other propeller-equipped aircraft, where an engine (piston or jet) is responsible for rotating the propeller(s). The propulsion on jet aircraft is given entirely by the engine (turbojet or turbofan). For the purpose of this study, we will refer it all as *powerplant*.

The *avionics* group is the combination of all flight, engine and navigation instruments, together with all the electronic equipment on board, essential for the various regimes of flight the airplane has been certified. In this group we can mention the automatic direction finder (ADF), very high omnidirectional range station (VOR) and global positioning system (GPS) as examples of navigation avionics, the very high frequency (VHF) and high frequency (HF) radios as communication avionics and the N_1 or engine pressure ratio (EPR) indicator as an example of engine-monitoring avionics.

Finally, the last group is the one that combines all other items and equipment of the aircraft. This group is composed of so many different items

that it can be referred as *others* without incurring in a serious error. Listed in this group are seats, galleys, interior panels, tires, etc.

Aircraft Cell Standardization

We can consider as having the same cell all airplanes from a single *family*, such as the Boeing 737-300/400/500, the 737-NG (-600/-700/-800/-900), the Airbus A318/319/320/321, and the Embraer 135/140/145. The differences between aircraft from a same family are usually few and usually relate to their length, capacity and powerplant variants (mainly thrust). Their piloting procedures and the maintenance procedures can be considered almost the same for simplification. However, this approach must be taken with caution: it does not mean that all Boeing 737 have the same cell, as it is widely known that the 737-200 is quite different from the –300/400/500 family, while both are different from the –NG family. This classification of separating through families takes into account the design and the aerodynamics characteristics, indeed both quite similar (if not equal) to the entire family. In the basic approach, and in the simplification herein used, it is of fundamental importance to know how to classify the aircraft into families, or the findings of the present study will not be valid.

It is interesting to note that, since all aircraft from a single family are usually operated almost in the same way, the family classification shown above immediately implies a substantial benefit when considering crew training programs. A crew trained to operate one type of aircraft within a given family can be easily switched to operate all the other aircraft of that family.

Powerplant Standardization

As mentioned before, the propeller is also a part of the engine-propeller group. On jet airplanes, we can say engine and engine-propeller indistinctly, because there is no propeller. As a follow-on to this preliminary study, a more detailed and complex analysis could consider fleets composed by all kind of aircraft (including aircraft with piston engines). In the present case, as a simplification, this paper will address engines as a whole, leaving the study of propellers' influence on standardization for the above mentioned follow-on more detailed study. In view of this, as highlighted in the previous section, we will refer to the term powerplant only.

If it were possible to separate the powerplant from the cell, we could see some interesting situations. A single cell can be equipped with more than one type of powerplant, and a single powerplant can be used with different cells, generating one or more of the following situations.

1. Same cell, same powerplant;
2. Same cell, different powerplant;

3. Different cells, same powerplant; and
4. Different cells, different powerplant.

Low-aged fleets tend to be formed around situation 1 (same cell, same powerplant). New entrant airlines, especially low-cost/low-fare carriers, tend to build their fleets aiming to extract the most positive results from this first situation. Middle-aged fleets, as the ones in a renewal process, can be commonly nested within situation 2 (same cell, different powerplant). On the other hand, situation 3 (different cells, same powerplant) is not commonly seen, but would be the case of a fleet composed by Boeings 707 and 737, that can be equipped with the same powerplant. Complementarily, situation 4 (different cells, different powerplant) is more common of small airlines with a relatively small fleet, in particular all-cargo operators with few routes or operating cargo charter flights.

But, again, for the purpose of this preliminary study, let us concentrate solely on the powerplant. They will be classified not only in regard to its manufacturer and type, but also to the extent of what we will herein refer to as variant or *dash*, something like a sub-type. This three-level classification is indeed complex, but it follows the same approach used for the two-level classification applied for the cell analysis discussed later.

Avionics Standardization

The study of avionics standardization is much more complex than the aforementioned cases. This is in great part due to the great variety of instruments and electronic on-board equipment. In order to picture yourself in this complex scenario, imagine being the captain or first-officer of an airline operating a Boeing 737-300 registered BR-BR1 on one day, and having to fly the next day another 737-300 registered BR-BR2, with instruments from different manufacturers and, worse of all, with these instruments mounted on different locations on the front and overhead panels. In the extreme, this could even lead to confusing the crew on a particular switch or on/off signal during an emergency situation, posing risks of catastrophic consequences. Moreover, maintenance personnel could also encounter problems with this confusing, multiple layout flight deck configurations while in the programming procedures of daily fleet maintenance.

This type of standardization can be easier to achieve as long as the carrier blocks a given batch of airplanes coming off the production line in direct sequence. In this case, even if not clearly demanded by the carrier, there is a tendency by the aircraft manufacturer to install avionics from the same supplier on all aircraft in that batch. In fact, a good level of standardization can be achieved within a same aircraft family when the avionics are at least of the same manufacturer or the same model. However,

nowadays only a few airlines are able to purchase batches of aircraft directly from the manufacturer. Leasing diverse aircraft from international lease companies is currently one of the most common forms of fleet composition.

Being a preliminary study, this paper will not address the complex issues of the standardization involving the avionics group and the others group. We encourage other follow-on studies to address in detail these and other groups not listed in this paper.

Economical Aspects of Fleet Standardization

It should be pointed out that using equipment from the same manufacturer may lead to significant savings in maintenance, spare parts inventory, tooling, training and buyer-supplier negotiations. The target of the negotiation shall not be to achieve short-term advantages, but rather mid- and long-term advantages. Brazilian carriers TAM and GOL are examples of this, with TAM with an almost all-Airbus fleet (A319/320 and A330-200s, plus still a few Fokker 100s), and GOL with a true all-Boeing 737NG fleet (737-700s and –800s). Although not being a target for the present paper, for a more detailed analysis of economical aspects of airline fleet standardization we recommend the approach put in discussion by Holloway (1997).

THE FLEET STANDARDIZATION INDEX (IPF)

Indexes (or indicators) are non-exact/non-precise tools to quantify a highly subjective aspect with no link to numerical data. Many indexes/indicators are commonly used in trying to allocate quantitative values, such as poverty, development, customer satisfaction, and others. In spite of their existing limitations the use of indicators is continuously growing. In fact, on one hand they are be labeled as non-precise and non-exact, on the other hand they permit making direct and uncomplicated comparisons, which can be used, understood and discussed by almost any individual. Indexes are essential, for example, in the cost-benefit analysis when evaluating the impact distribution of a project.

Comparing fleets is very difficult when the variety of types and models of aircraft and powerplants is such that allows almost infinite combinations between them. Moreover, discussion about fleet standardization is as difficult as comparing them. To assist in this difficult comparison task this paper introduces an index herein christened *Fleet Standardization Index*, or IPF (for the initials in Portuguese of *Indice de Padronização de Frotas*).

As mentioned before, the formulation of the IPF is herein presented in its initial form of quantifying the level of fleet standardization. Despite this preliminary and simplistic approach, it is already possible to have a fairly good idea about the status of airlines' fleets. In view of this, and considering

its current preliminary format, the IPF will be initially composed of two aspects: the standardization of airplanes' cells and powerplant. The development of the IPF formulation was made on a semi-empirical basis, starting with the following assumptions:

1. The higher the number of different manufacturers of aircraft/powerplant, the lower is the level of standardization—consequently the IPF will be found proportional to the inverse of the number of manufacturers;
2. The higher the number of different models (families) of airplanes/powerplants from the same manufacturer, the lower is the level of standardization—as seen above, the IPF is proportional to the inverse of the number of different models for each manufacturer;
3. The same analogy can be used for the dashes (variants, sub-types) of powerplants—this put, the IPF is proportional to the inverse of the number of powerplant variants, for each model and manufacturer.

The two aspects shown above will lead to a pair of auxiliary indexes: the *Cell Standardization Index* (or IPC) and the *Powerplant Standardization Index* (or IPM). In further studies, other indexes could be added in the IPF determination (i.e., IPA for Avionics, and IPOPI for Other Parts and Items). So, the initial formula for IPF is shown below in Equation 1:

$$IPF = \alpha_1 \times IPC + \alpha_2 \times IPM\ ,\ \ where\ \alpha_1 + \alpha_2 = 1 \qquad (1)$$

The definition of α_1 and α_2 values will be the result of practical studies and surveys, where the researcher will be able to identify and measure the influence of each type of standardization on the IPF. As a matter of simplification and in order to obtain numerical results for this preliminary study, we will assume a case where the values are 0.6 to α_1 and 0.4 to α_2. For this, the expression (1) becomes:

$$IPF = 0.60 \times IPC + 0.40 \times IPM \qquad (2)$$

The next and most important step is to obtain the equations for IPC and IPM. Considering the similarity between both them and again as a matter of simplification, we will address either one and then extrapolate the result to determinate the other. Later on we will mention some IPC and IPM formulas that were tried out by the authors, but were found to be non-effective.

Initial Formulas

Initially, with the approach and considerations discussed earlier, it was intended to pursue directly the formulation of indexes IPC (cell) and IPM (powerplant). However, a major concern arose when turning values that are proportional to the airplanes/powerplant quantities into a single expression. The intermediate solution adopted was to create partial indexes calculated for each manufacturer. These will be herein named *Cell Standardization Partial Index* (IPPC) and *Powerplant Standardization Partial Index* (IPPM).

Cell Standardization Index (IPC)

The number of airplanes from each manufacturer is used as the ponderable factor of the index, being the number of models the main quantifying factor. Due to its inverse proportionality, the IPPC expression was obtained as:

$$IPPC = \frac{\text{total number of airplanes from one manufacturer}}{\text{number of families from that manufacturer} \times \text{total fleet}} \quad (3)$$

With the IPPC in hand, tests were run in order to establish the correct formulation for the IPC. After several tests, the emerged IPC equation was:

$$IPC = \frac{\sum \text{IPPC}}{\text{number of manufacturers}} \quad (4)$$

In such a way, it was possible to ensure that the considerations seen in previous sections would be met, being the IPC is inversely proportional to the number of manufacturers.

Powerplant Standardization Index

The same approach was used to develop the formulation for the IPM index. Nevertheless, as the powerplant considerations have a further level of detailing (different dashes and variants of powerplant available), an adjustment on the IPPM was found to be necessary. This has emerged in another index, herein called *Model Specific Powerplant Standardization Index* (IPPMM). All expressions, for IPPMM, IPPM and IPM, are presented below.

$$IPPMM = \frac{\text{number of powerplants of a model}}{\text{(number of dashes of same model} \times \text{total number of powerplants)}} \quad (5)$$

$$IPPM = \frac{\sum \text{IPPMM}}{\text{number of models from a manufacturer}} \quad (6)$$

$$IPM = \frac{\sum \text{IPPM}}{\text{number of manufacturers}} \quad (7)$$

Practical use of the equations developed

In order to test and present a preliminary practical use of the above listed formulas, a sample airline AIR STUDIES will be considered. This airline operates a fleet of aircraft from three different manufacturers, ALFA, BRAVO and CHARLIE, as listed on Table 1. The sample powerplants are listed in the right column of Table 1 and also on Table 2:

Table 1: Fleet operated by sample airline AIR STUDIES

Maker	Model	Qty	Type	Powerplant
ALFA	ALFA-100	4	Twin jet	W-1-2
		3	Twin Jet	W-1-3
	ALFA-200	9	Twin Jet	W-7-2
BRAVO	B-1	2	Twin Jet	W-1-2
		8	Twin Jet	Y-90-F
	B-2	12	Twin Jet	Y-100-A
		25	Twin Jet	Y-100-B
	B-3	8	Twin Jet	Y-2000-Z
CHARLIE	CH-10	12	Twin Jet	Y-100-C

Table 2: Powerplant combinations used on sample airline AIR STUDIES airplanes

Manufacturer	Model	Number of Variants Dashes	Total Quantity
WALKER MOTORS	W-1	2	9 x 2 = 18
	W-7	1	9 x 2 = 18
YIELD AVIATION ENGINES	Y-90	1	8 x 2 = 16
	Y-100	3	37 x 2 = 74
	Y-2000	1	2 x 2 = 04

Calculating the IPC (Cell Standardization Index) for carrier AIR STUDIES:

Manufacturer ALFA: 2 different cell models, 16 airplanes total:

$$IPPC = \frac{16}{2 \times 83} = 0.096 \tag{8}$$

Manufacturer BRAVO: 3 different cell models, 55 airplanes total:

$$IPPC = \frac{55}{3 \times 83} = 0.221 \tag{9}$$

Manufacturer CHARLIE: 1 cell model, 12 airplanes total:

$$IPPC = \frac{12}{1 \times 83} = 0.145 \tag{10}$$

The IPC for AIR STUDIES is:

$$IPC = \frac{0.096 + 0.221 + 0.145}{3} = 0.154 \tag{11}$$

The next step, using Table 2 data, is to obtain the IPM for our virtual AIR STUDIES carrier. Together with the calculated IPC, it will compose the IPF as shown in formula (2).

Manufacturer Walker: 18 W-1 engines of 2 dashes and 18 W-7 engines of a single dash.

$$\begin{gathered} IPPMM_{W-1} = \frac{18}{2 \times 166};\ IPPMM_{W-7} = \frac{18}{1 \times 166}; \\ IPPM_{WALKER} = \frac{0.163}{2} = 0.082 \end{gathered} \tag{12}$$

Manufacturer YIELD: 16 Y-90 engines of a single type, 98 Y-100 engines of 3 types and 16 Y-2000 engines of a single type.

$$IPPMM_{Y-90} = \frac{16}{1 \times 166};\ IPPMM_{Y-100} = \frac{98}{3 \times 166};$$
$$IPPMM_{Y-2000} = \frac{16}{1 \times 166};\ IPPM_{YIELD} = \frac{0.389}{3} = 0.130 \tag{13}$$

Follows the IPM for AIR STUDIES:

$$IPM = \frac{\sum IPPM}{\text{number of manufacturers}} = \frac{0.212}{2} = 0.106 \tag{14}$$

Finally, the IPF is obtained with Equation 2:

$$IPF = 0.60 \times 0.154 + 0.40 \times 0.106 = 0.135 \tag{15}$$

It is important to observe that this result, alone, has no meaning. However, when advancing to the next step of comparing the indexes for different airlines it would be possible to notice which carrier has a higher or lower level of standardization. Moreover, it can be used as a strategic tool in assisting and analyzing opportunities for fleet renewal.

REJECTED FORMULAS

In this section we will present some of the rejected formulas. Those herein listed were discarded because the results obtained were found to be incorrect and/or inconsistent in some particular situations. However, they were extremely valuable in the development of the initial formulas presented above. As a matter of simplification, the formulas below will only be presented with its main discarding reason. Its development will not be presented.

First rejected formula

The following formula was the first to be rejected during the development of the indexes.

$$IPC = \sum IPPC \tag{16}$$

The reason for discarding this formula (Equation 16) was the fact that the IPC (or IPM) would increase if the number of manufacturers had also increased. When analyzing the cell (or the powerplant) individually, having

aircraft from more than one manufacturer, clearly the fleet will be less standardized, thus directly conflicting with what would be set in the formula.

Second rejected formula

The tests following the previous rejection paved the way to discarding the equation shown below.

$$IPM = 1 - \sum IPPM \tag{17}$$

This formula solved the initial problem found with Equation 16, but another problem of the same sort was then created. At that point the IPM (or IPC) increased with the increase in the number of models, what would be also incorrect. The next step taken to re-analyze and run other tests came to solve this problem, leading to the correct formulas, presented in the previous sections.

General Considerations for Future Development

As highlighted previously, the present approach does have limitations, the primary being that it does not yet consider the avionics and the others groups, both extremely relevant for a strategic fleet planning in the real complex world of airline planning. However, these limitations can be minimized with further analysis and research. The limitations identified during our study and some possible solutions are presented and discussed below.

The first drawback of the present preliminary development phase is the low capability of the IPF index in allowing planners not only to compare different fleets or situations but also its low capability in presenting them the correct feeling of quantity. In other words, a simple verification of the IPF value should be sufficient to understand the degree of standardization of that particular airline, which is still not the case with the equations herein depicted. In fact, the IPF index developed herein is sufficient only to conduct comparisons between different airlines (different fleets).

A more in-depth mathematical approach, with the analysis of sample cases in a crescent or decreasing standardization sequence, could lead to a robust solution in helping correct the above mentioned drawback. Meanwhile, it is the understanding of the authors that the basis for calculation of IPF and related indexes and sub-indexes could be kept unchanged. The central point could be the linearization of results, and the task is to find a mathematical method to perform it. The authors have not yet used exponential factors, but it is believed that it could be a good way to

achieve the desired results. Follow-on studies are being planned in this direction.

Another important limitation that does deserve attention is the numerical compatibility between IPC and IPM. At the present moment the values obtained for both seem to be incompatible in terms of dimensions, while the ponderable (weight) system used has been arbitrary. The follow-on study, now in its initial phase (Phase 2 of the entire original research project), is also being aimed at the necessity of the final IPF being obtained from comparable and compatible IPC and IPM values, to be sure that the influence of cell and powerplant standardization are correctly balanced and accounted for. A reasonable form to pursue is to have adequate α_1 and α_2 values in the first formula (Equation 1), thus pointing to a change in the expression (Equation 2). Nevertheless, the basis for the IPF calculation will still remain the same, as the results herein exposed remain valid for comparison purposes.

It is the understanding of the authors that a complex mathematical effort shall be employed to develop the final formula, which would then minimize to the greatest extent possible the limitations discussed and presented above. This quantitative effort may include the measurement of influences and the linearization of both IPC and IPM.

The authors encourage other researchers to collaborate in this effort, even if departing from the original approach taken by the present study.

CONCLUSIONS AND CONSIDERATIONS

The Fleet Standardization Index (IPF), as presented in this pilot study, allows the quantification of a highly subjective aspect: the level of standardization between airline fleets. The comparison between two or more different fleets, from different airlines or simulating changes in an actual airline, can be made with the IPF.

However, some drawbacks have been identified by the authors in the formulation of the IPF itself and its components IPC (for the cell) and IPM (for the powerplant). Although limiting its effectiveness as a sole index (when not used to comparing different fleets or carriers), the problems identified can be minimized to a great extent. Follow-on studies to the research herein presented are already being drafted in order to realign the formulations. When this is achieved, it will permit the usage of the IPF index alone, without the need for comparison between different fleets and/or carriers (as the current model dictates).

For this, the authors encourage other researchers to analyze and consider in more detail the multiple influential aspects of airline fleet standardization in order to verify the level of influence of each factor in the final airline IPF.

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FUTURE AIRPORT CAPACITY UTILIZATION IN GERMANY: PEAKED CONGESTION AND/OR IDLE CAPACITY

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ABSTRACT

The air traffic situation at German airports is characterised by intense capacity utilisation at the most important airports and rather low utilisation at many other airports. Although since 2001 overall traffic stagnates, air transport movements (ATMs) at hub airports are growing further. In this paper, we will describe airport traffic and capacity, discuss traffic forecasts and compare future volumes of ATMs with capacity at German airports. Means of de-peaking the spatial utilisation of airports will be presented. It will be shown that in less than 10 years time Germany needs additional runway capacity, which will most likely not be provided. Lacking this solution supply spreading measures and business models are discussed.

INTRODUCTION

The present situation in air transportation in Europe, and in Germany in particular, is characterised by diverging phenomena. After many years of strong growth the demand for air transport services is stagnating in some markets and even going down in others. All together, the traffic at the 18 international airports of Germany has reached a peak volume of 142 million passengers in the year 2000. In the two following years the traffic has dropped to 135 million passengers. This trend continues at present even as

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new demand-reducing factors, such as the proliferation of the SARS disease in Asia, cause many potential passengers to refrain from travelling.

While the overall demand is declining the demand for low fare services—as offered by low cost carriers (LCCs)—is growing strongly. After Ryanair more or less introduced this kind of no frill services in Germany in 1999 several other start-ups took up this supply idea in 2002 and have attracted a great and growing number of passengers, primarily on services to Berlin and European destinations such as London, Milano, Pisa, and Barcelona. This means that the decline of demand occurs solely on services of the traditional network airlines, although they, too, have started to offer low fare services on a growing number of traffic relations.

Airport capacity has been a scarce resource at some of the busiest airports even before the year 2000. With the decline of traffic the bottleneck situation did decrease, however, severe traffic delays continued to prevail in daily peak hours at Frankfurt and Düsseldorf and to some degree at Berlin-Tegel. More importantly, while the overall traffic decreased, air transport movements (ATMs) at the congested hub airport Frankfurt and at the secondary hub München went up by 3% from 2000 to 2002. At all other non-hub airports ATMs went down by almost 6% in the two year period of weak demand. Traffic was thus concentrated and channelled through the hub airports, whereas most of the other airports—with the exception of Düsseldorf and Berlin-Tegel—do not have severe capacity problems and would welcome more traffic. Only recently did traffic begin to grow at those airports where LCCs started services, in particular in Köln/Bonn.

Air traffic forecasters assume that the traffic will resume to the former growth trend again, although with a changed supply pattern. It seems that LCCs will successfully operate and take up a growing part of the total market. Given the present capacity problems and the political difficulties to enhancing airport capacity, the question is whether or not airports will be able to accommodate the traffic growth without deteriorating the quality of service to levels intolerable to passengers and airlines. Do the busiest airports continue to struggle with the need for more capacity while the other airports—with ample capacity—are unable to reach higher market shares?

In the following, we will (a) describe airport traffic and capacity, (b) compare traffic volumes with capacity, (c) discuss long term forecasts of air transport demand, (d) describe two scenario dependant forecasts of flight movements at German airports, (e) compare future peak hour volumes of ATMs with the capacity of these airports, and finally, (f) discuss whether or not there are possibilities of spreading the utilisation of airport capacity more evenly.

TRAFFIC VOLUMES AND STRUCTURE AT THE INTERNATIONAL AIRPORTS IN GERMANY

Germany, a country with a population of about 82 million people and a size of nearly 360,000 square kilometers, has a dense network of classified airports. The highest category is made up by 18 international airports which—together with some 10 so-called regional airports—serve primarily the public air transport system with scheduled and charter services on domestic and border crossing traffic relations. Most of the traffic is handled by the 18 international airports although at some of the regional airports, like in Paderborn and Hahn, traffic volumes are exceeding 1 million passengers per year. Hahn has been converted from a military base to a civil airport and has been chosen by Ryanair as a hub in Germany.

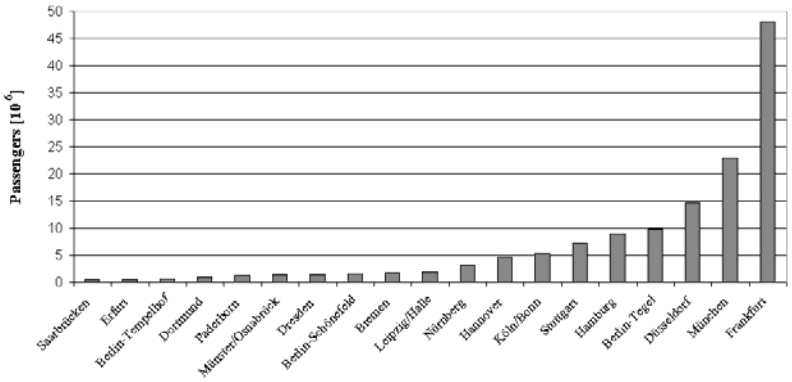
In 2002, the international airports handled a traffic volume of 135 million passengers enplaned and deplaned and about 2 million flight movements in primarily scheduled services. Since 1992, the second year after the reunification of Germany, passenger traffic has grown by 56% (4.5% annually) and the ATM volume by 32% (2.8 % annually). Air transport has thus grown much faster than the classic modes of rail and car, however, the growth came to a halt in 2001 after 9/11.

In figures 1 and 2, passenger volumes and ATMs of German international airports in 2002 are shown, ranked by the size of traffic volume. The biggest airport is Frankfurt with 48 million passengers and 458,000 flight movements of which around 60% belonged to the home-carrier Lufthansa which operates its main hub there. Due to capacity problems—Frankfurt has two parallel runways and a third runway used exclusively for take-offs, with operations dependant on each other—Lufthansa transferred a growing part of its hub operations to München, the second biggest airport in Germany, with 344,000 ATMs (and 23 million passenger). As a consequence, München airport augmented the traffic volume from 2000 to 2002 by 7.8%, whereas the total ATM volume of Germany decreased by 2.5% in the same period. The Frankfurt traffic volume stayed about constant in these years.

Before München became an airport with growing hub functions it was Düsseldorf airport that ranked second after Frankfurt. In 2002, Düsseldorf had a traffic volume of 14.6 million passengers and 190,000 ATMs. Great deals of the passengers are using the airport for tourism flights, primarily into Mediterranean resort areas. The catchment area of Düsseldorf airport is the Rhine-Ruhr District with about 10 million people, predominantly living in urban areas, which it has to share with other airports, in particular Köln/Bonn and Dortmund. Like Frankfurt and Berlin-Tegel, Düsseldorf has two parallel runways separated by about 500 metres so that flight operations are not independent. In contrast to these airports, Düsseldorf can normally

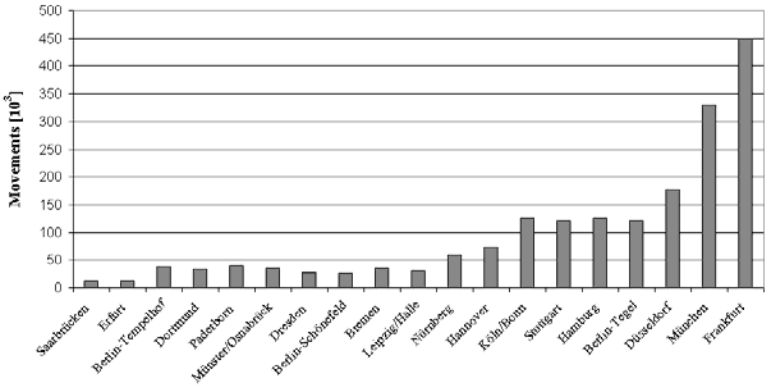
use only one runway, since administrative regulation has set forth the total capacity equal to a single-runway capacity.

Figure 1. Number of passengers at German international airports in 2002



Source: *Annual statistics 2002.* (2003). Stuttgart, Germany: German Airport Association.

Figure 2. Number of air transport movements at German international airports in 2002



Source: *Annual statistics 2002.* (2003). Stuttgart, Germany: German Airport Association.

In Berlin, 12 million passengers and 213,000 flight movements were handled by an airport system consisting of Berlin-Tegel, the main airport, Tempelhof and Schönefeld. While Tegel carries more than 80% of the total passenger traffic (and 60% of ATMs) and operates near terminal capacity, traffic demand in Tempelhof and Schönefeld is declining. Since the reunification of Germany and the fall of the Berlin Wall, the States of Berlin and Brandenburg plan a single airport for Berlin at Schönefeld with enough

capacity and lower environmental damage than Tegel and Tempelhof cause, up to the present, however, the planning has not yet reached an advanced stage.

Hamburg and Stuttgart are two other busy airports, with almost 9 and 7 million passengers, respectively. Hamburg has a runway system consisting of two runways crossing each other which handled 150,000 movements in 2002, roughly the same traffic volume as Stuttgart (144,000 ATMs) which has to rely on a single runway. At both airports, non-commercial flight movements account for about 25,000 movements. A great part of these movements may be suppressed and diverted to other airports if lack of runway capacity would become a problem for scheduled and non-scheduled commercial operations, as has been the case already in Frankfurt and in Düsseldorf.

The airports Köln/Bonn and Hannover have open parallel runway systems allowing for independent operations, with 85,000 movements in 2002 they handled volumes well below the capacity limit. Leipzig airport also has two runways; they are, however, not parallel but located at an angle to each other. For the time being, the second runway is used more for environmental than for capacity reasons; the traffic volume of Leipzig was not higher than about 40,000 ATMs in 2002.

All other international airports have single runways for the traffic with scheduled and charter flights. They are located in Bremen, Dortmund, Dresden, Erfurt, Münster, Nürnberg and Saarbrücken, with traffic volumes ranging from 78,000 in Nürnberg and 15,000 in Saarbrücken. Dortmund has been added to the category of international airports only recently when it was supplied with a runway long enough to handle flights with aircraft types typically operated in scheduled and charter traffic, that is, the B 737 and A 320 family.

In addition to the network of international airports there are 10 regional airports which serve to some degree the same task; that is, to provide access to the national and international services in scheduled and charter traffic. Altogether these airports handled 64,000 movements, which carried 4 million passengers, about 3% of the total air traffic volume of Germany.

It can be concluded from the preceding that Germany has a substantial number of regionally distributed airports—almost 30 airports with nearly 40 runways serving the public air transport system of a population of over 80 million people—but with the traffic heavily concentrated at a few airports, which are more or less working at capacity level. More than one-third of the German passenger traffic is handled by Frankfurt alone, and almost two-thirds of the total is served by the three airports at Frankfurt, München and Düsseldorf. There are 27 airports that handle only about one-third of total passenger traffic. Are there chances or inherent mechanisms to

change this concentration towards a more evenly distributed utilisation of airport infrastructure?

LONG-TERM DEVELOPMENT OF AIR TRANSPORT DEMAND

The past development of commercial air traffic was characterised over many years by strong growth both world wide, as well as in Germany. Only since the year 2001 has the growth trend been interrupted by a stagnation phase caused by several factors: in particular 9/11, the weak economic situation, the Iraq war, and, more recently, the SARS disease in Asia. The former growth varied by market segment and region, and was dependant on the unit in which the traffic is described. The transport volume (passengers, freight, flights) had not grown at the same pace as traffic performance, measured in passenger kilometres (kms), tonne (metric ton) kms, or flight kms, since air travellers have used flights to ever more distant destinations.

Forecasts of the traffic of a region or an airport refer normally to the traffic volume, that is, in particular, the number of passengers transported and the number of flights. As an example of a regional forecast, we will shortly describe the long-term forecast of the German Aerospace Center (DLR) for Germany. This forecast includes travel demand, passenger traffic volumes and the number of flights at the international airports of Germany for different scenarios. On the other hand, global forecasts deal typically with the traffic performance; a well-known example of this type is the forecast of the International Civil Aviation Organisation (ICAO). We describe shortly the most recent ICAO forecast, which has been elaborated by the Forecast and Economic Analysis Support Group (FESG) of the Committee on Aviation and Environmental Protection (CAEP).

Global ICAO/CAEP- Forecast 2020

The ICAO/CAEP-Forecast is a result of work within ICAO and the Forecast and Economic Analysis Support Group (FESG) of ICAO/CAEP and has been finalised in early 2003; that is, before the Iraq war and the spreading of the SARS disease. The group took into account, however, world wide economic development as seen by various institutions at that time. The forecast method corresponds with the one that has been used often times in ICAO-Forecasts (see, for example, ICAO, 2001).

The method consists basically of a function describing the global air travel demand (passenger kms) in relation to the world wide gross domestic product (GDP) in real terms and the average passenger-revenue-per-passenger kms (yield) in real terms in scheduled air services. In addition, forecasts available from Boeing, Airbus, Rolls Royce and Pratt & Whitney, and former ICAO forecasts were consulted and model results were adjusted

when appropriate in the light of discrepancies between forecasts. The results of this so-called consensus forecast of FESG are presented in Table 1.

Table 1. Global forecast of air travel demand, 2000-2020

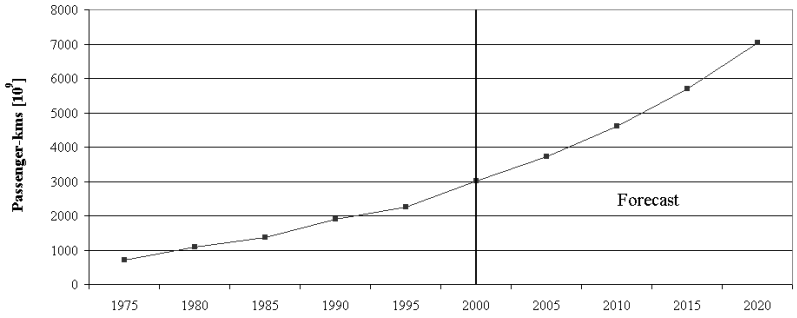
Average Annual Growth Rate	*Growth Factor*	*2000-2020*
International	*4.9*	*2.6*
Domestic	*3.5*	*2.0*
Total	*4.3*	*2.3*

Source: *Traffic and fleet forecast.* (2001). Montreal: ICAO Committee on Aviation Environmental Protection, Forecast and Economic Analysis Support Group.

Regarding the development over time it was assumed that the growth in the first five-year period would be much smaller than in the following periods and would slow down again towards the year 2020. Altogether the passenger traffic (passenger kms) will increase in the 20-year forecast period by 130%. Since the traffic declined world wide in 2001 and 2002 the total growth is higher in the 18-year period.

As can be seen in Figure 3, ICAO/CAEP has thus forecast a long lasting growth of world wide travel demand, despite the ongoing development of factors affecting air traffic negatively. This long-term trend follows the past trend which was also characterised by strong growth over a long period: In the 30-year period from 1971 to 2001 global air traffic has grown by the factor of six!

Figure 3. Forecast of scheduled air traffic world wide until 2020



Source: *Traffic and fleet forecast.* (2001). Montreal: ICAO Committee on Aviation Environmental Protection, Forecast and Economic Analysis Support Group.

This ICAO/CAEP forecast is based, among others, in the methodological hypothesis of unrestrained conditions in the air traffic system. This basic assumption becomes more and more questionable as the

busy airports world wide approach capacity levels. In order to verify the significance of the forecast, a volume-capacity comparison should be conducted—an exercise probably too cumbersome to carry out globally. For Germany, this has been done in the DLR-Forecast.

DLR-Forecast of German Air Traffic 2010

The DLR-Forecasts serve—among others—the planning of federal transport networks of the Federal Government and the airport planning of the States (Länder) of Germany. The methodological approach includes the forecast of demand (journeys by air, freight), of passenger flows on origin-destination (O-D) routes, their assignment to the links served, and the estimation of flights on these links based on passenger volumes, and thus the traffic of passengers and flight movements (take-offs and landings) at airports.

The background of the demand forecast is the *unconstrained reference scenario,* the main hypothesis of which is the provision of sufficient capacity at airports and in air space so that airlines can develop their offer reflecting, first of all, demand preferences. The main reason for basing the forecast on this hypothesis is the fact that the methodology of forecasting demand does not require a feedback procedure caused by limited capacity. It is in following scenarios that the hypothesis is questioned and strategies of market adaptation of airlines and reactions of travellers on supply changes in relation to system bottlenecks are assumed. A suppression of demand, however, has been excluded in all forecast scenarios.

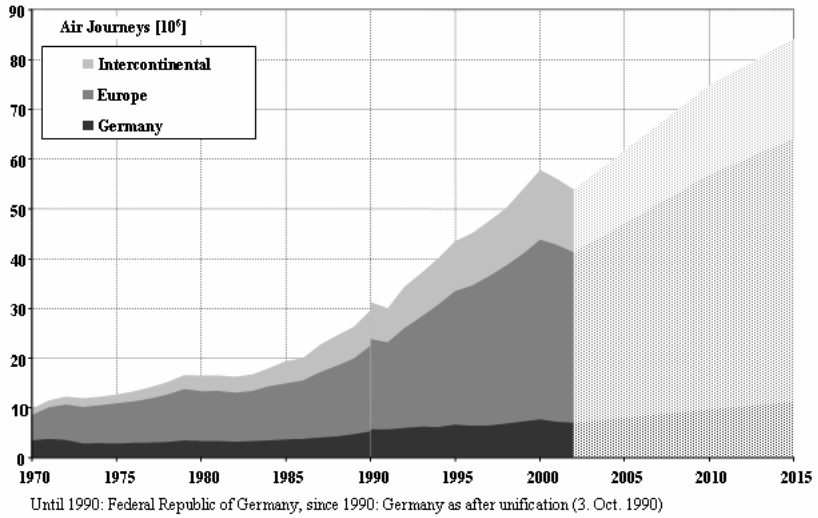
For the year 2015 the global air travel demand of Germany has been forecast as well; under unconstrained system conditions the total demand for air transport will reach a volume of about 84 million journeys in that year, this being 9 million journeys more than in 2010. Although the pace of growth will retard somewhat as compared with the period before we still have to face a considerable amount of additional traffic in that decade.

In the past the demand has grown to its peak level so far of 58 million air journeys in the year 2000, since then the demand dropped to 54 million in 2002. As compared with the year 2000 the demand will grow annually by an average of 1.7 million journeys until the year 2010, however, compared with 2002, the annual growth is more than 2 million. This is somewhat less than in the 1990s when the growth was strongest over a period of 9 years between 1991 and 2000, but corresponds roughly with the absolute annual growth in the 20-year period from 1980 until 2000.

The future number of passengers enplaning and deplaning at the German airports selected for the forecast (18 international airports in the past, 16 international airports in the future with one airport in Berlin, plus the 4 regional airports Kiel, Paderborn, Friedrichshafen and Augsburg) which

correspond to the demand described above (75 million journeys) amounts to about 185 millions in 2010, in the year 2000 this volume was 144 million passengers (in 2002: 137 million).

Figure 4. Development of air travel demand of Germany



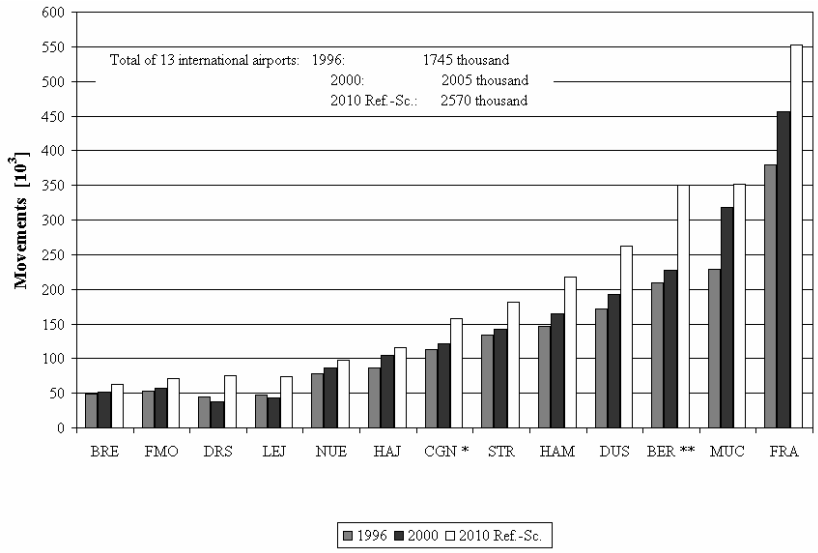
Sources: *Monthly air transport statistics 1970-2002*. (2003). Wiesbaden, Germany: Federal Statitical Office; Urbatzka, E., Focke, H., Stader, A., and Wilken, D. (1999). *Air transport scenarios reflecting capacity constraints at German airports.* Koln: DRL.

The total number of ATMs at airports consists of take-offs and landings of passenger flights in scheduled and charter traffic, freight and mail flights, and other flights in commercial and non-commercial traffic. In 2000, these flights amounted to 2.1 million take-offs and landings on the airports selected (2002: 2.05 million), and traffic has doubled in the 15-year period from 1985 to 2000.

In the unconstrained reference scenario the number of passenger flights in the year 2010 is estimated on the basis of a continued liberalization of markets and frequency competition among airlines. This means for the procedure of calculating flights that the variable mean size of aircraft in service on any link (as expressed in the seat capacity per flight) stays rather constant, as has been the case on liberalized markets in recent years. A similar hypothesis is retained for the variable average load factor, which varies strongly between link types, however not significantly over time. There has been though a slight increase of the load factor on intercontinental flights.

With these assumptions the passenger flight volume at the primarily international airports in Germany will grow from 1.4 million ATMs in 1996—a base year of the forecast— respectively from 1.7 million ATMs in 2000 to more than 2.2 million passenger flight movements in 2010. Including all other movements we can expect around 3 million take-offs and landings in 2010, given the capacity at airports and in the controlled air space allowed for it. In this reference scenario, Frankfurt, the main hub airport of Germany, would have to handle 550,000 movements, while München, being mainly an O-D traffic airport, could expect 350,000 movements (see Figure 5). As can be seen, too, the actual development in München has already gone in another direction; due to the actual capacity problems at the principal hub at Frankfurt, Lufthansa has moved a growing part of hub-related operations to München. This was the main reason for the strong growth of ATMs there; no other airport had a comparable strong growth during the last years as München.

Figure 5. Number of air transport movements at German international airports in 1996, 2000 and 2010



* CGN without freighters during the night
** BER = 3 air-ports, in 2010: one airport BBI

Source: *Montlhy Air Transport Statistics: 1996.* (2000). Wiesbaden, Germany: Federal Statistical Office**;** Urbatzka, E., Focke, H., Stader, A., and Wilken, D. (1999). *Air transport scenarios reflecting capacity constraints at German airports.* Koln: DRL.

The strong increase in flight movements in Berlin is partly caused by the assumption that, from a catchment area of around 3.5 million people, Berlin would have a single airport with enough capacity to attract a great number of O-D services on European and intercontinental relations. Berlin has instead three airports and many domestic services which serve also as feeder links for European and intercontinental services, in particular via Frankfurt and München. The fact is that Berlin has not yet a single direct scheduled link to an intercontinental destination.

What can be seen in Figure 5 as well is the continuing concentration of services at a few airports; that is, Frankfurt, München, Berlin and Düsseldorf. The assumptions of the reference scenario are such that both O-D services and hub-and-spoke services will be offered in a competitive market environment. Therefore, a greater deconcentration of services could not be expected as a result of the reference scenario.

CAPACITY SURPLUS AND CONSTRAINTS

The question is now whether or not the airports can accommodate the forecast traffic volume. Regarding the different system elements of an airport concerning capacity the runway system seems to be the most critical one. In Germany, terminal or apron capacity can normally be augmented without problems in most cases, whereas for the expansion of runway capacity, a public project approval procedure is necessary. This approval process is very complex and time consuming. Examples are the construction of the runway west at Frankfurt or the realisation of the new München airport which took nearly 30 years from first plans until the beginning of operations.

Runway capacity is not a constant term but rather a function of a lot of variables like the configuration of aircraft in terms of size and propulsion, ratio of take-off and landing, rules of air traffic control (ATC), weather conditions, etc. Therefore, in order to compare runway demand (in terms of air transport movements) with capacity (of the runway system), the composition of aircraft must be the same in the demand forecast as in the capacity function. The comparison of demand and capacity can be realised on a yearly or hourly basis. A comparison on a yearly base can only be used for rough planning of airports, for instance, whereas to determine capacity reserves of a runway system, a smaller time unit is required. It is good practice to measure the capacity as an hourly value.

For the present year, runway capacity is established by the German Air Traffic Control Organisation (DFS) according to the local air navigation infrastructure (DFS-capacity) and by the Federal Ministry of Transport (coordinated capacity) for the Scheduling Coordinator who uses these values for the strategic planning of take-off and landing slots at the coordinated

international airports (Figure 6). The difference of the two concepts—DFS-capacity and coordinated capacity—is that the DFS-capacity value is related to the local air navigation infrastructure whereas the coordinated capacity value takes account of all actual restraining factors of the airport. For the years to come, capacity forecasts are needed which are based on the same assumptions regarding the aircraft size composition and traffic mix as traffic forecasts. Such capacity forecasts are not yet available.

Figure 6. Hourly runway capacity values for German airports, Winter season 2000/2001

Airport	Runway System	Runway Length	CC	DFS
		[meters]		
Berlin--Schönefeld	single; parallel not in use	3000/(2700)	24	30
Berlin--Tegel	parallel (dependent)	2400/3000	34	36
Berlin--Tempelhof	parallel (dependent)	2100 (1700)/2100	30	30
Hamburg	2 intersecting	3250/3670	51	54
Bremen	single	2040	15	30
Hannover	parallel	2340/3800	40	60
Münster/Osnabrück	single	2170	22	25
Düsseldorf	parallel (dependent)	2700/3000	38	38
Köln/Bonn	parallel + intersecting	1865/3815 + 2460	52	52
Frankfurt	parallel (dependent) + TO	4000/4000 + 4000	78	78
Stuttgart	single	3345	36	40
Nürnberg	single	2700	30	30
München	parallel	4000/4000	82	82
Leipzig/Halle	dual (dependent)	2500/3600	20	40
Dresden	single	2500	18	30
Dortmund	single	2000	n.a.	n.a.
Saarbrücken	single	2000	20	20
Erfurt	single	2600	18	22

CC - Coordinated Capacity Value
DFS - German Air Traffic Control Organization (DFS) Capacity Value
TO – Take-off
n.a. – not available
Source: *Manual of airport capacity.* (2001). Frankfurt, Germany: German Air Traffic Control Organisation. *Aeronautical information publication.* (2001). Frankfurt, Germany: German Air Traffic Control Organization.

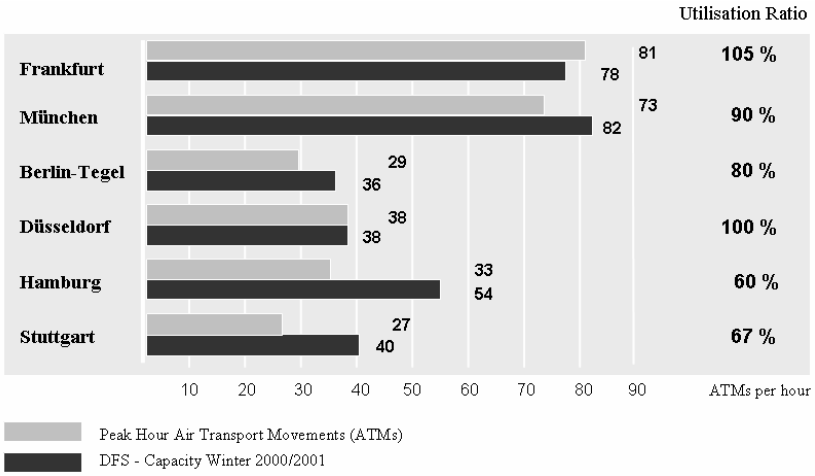
In long-term forecasts, traffic volumes are typically estimated on an annual basis. Therefore, the annual number of ATMs has to be converted into peak hour loadings. The question is then which peak hour to select. Choosing the hour with the highest traffic volume in a year creates a danger of over dimensioning facilities in a planning situation; on the other hand, if the hour of average daily traffic is compared with the runway capacity then an airport planned accordingly would have to struggle with over-loadings and thus losses in operational quality. Hence, DLR did not choose the hour with the highest traffic of a year but rather a highly charged hour within all operating hours of an airport in the course of a year which has about 6,500 to 8,500 operating hours depending on night curfew. The empirical functions

differentiated by runway system type showed that the quantity of flights in this hour corresponds to the value that is ranking at the 300th place of all operating hours. We use this hour—defined as the 5%-peak hour—as a typical peak hour for the volume-capacity comparison.

CAPACITY UTILISATION IN THE UNCONSTRAINED REFERENCE SCENARIO 2010

For answering the question of whether the forecast ATMs in the 5%-peak hour can be handled by the airport runway system, these peak hours are compared with capacities of the busiest airports in Germany. Regarding the year 2000—the year with the highest demand so far and not yet influenced by terror, economic slump and war as the following years—one can see that Frankfurt and Düsseldorf handle 81 and 38 movements in the peak hour, respectively, which is similar to the capacity value ATC has determined for the runway systems in this period (Figure 7). The other airports, shown in the diagram, still have a capacity surplus, especially Hamburg and Stuttgart.

Figure 7. Volume versus capacity comparison of German airports, 2000



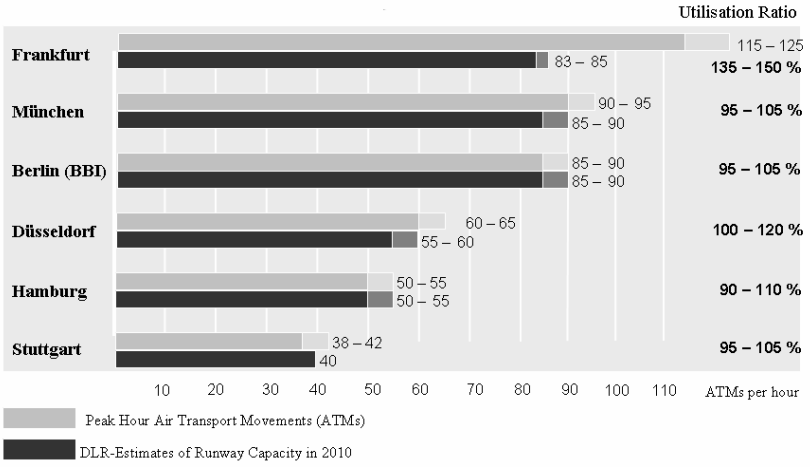
Sources: *Aeronautical information publication.* (2001). Frankfurt, Germany: German Air Traffic Control Organisation; calculation of peak hour movements by DLR.

For the year 2010 the picture will change dramatically. The result of the volume-capacity comparison in the unconstrained reference scenario shows that the forecast ATMs of the six busiest airports are nearly at or exceed the runway capacity if there is no expansion of the present capacity (Figure 8). Lacking capacity functions for future traffic and ATC-conditions, we have estimated capacity values of the runway systems for 2010 on the basis of

discussions about the development of past capacity values over time, of future traffic composition and of the likely regulatory environment of ATC.

Düsseldorf remains overloaded even if both runways can be used without restrictions. The ATMs at Frankfurt, the main hub in Germany, exceed the present runway capacity by about 50%, if there is no capacity expansion. München will reach the capacity level in the reference scenario in 2010 with traffic serving primarily the O-D-demand of its own catchment area. München will certainly become overloaded if the airport will, in addition, have to take over hub functions, as is already the case with Lufthansa hub operations via München. The airports of Hamburg, Stuttgart and Berlin—along with the new Berlin-Brandenburg International (BBI) airport still planned and regarded as the only operating airport in Berlin after start-up—will hardly be able to handle the movements estimated in the reference scenario. This means that, in reality, this transport scenario is of a theoretic nature only and will not and cannot materialise, since capacity over-loadings of this order of magnitude cannot be handled by the runway systems.

Figure 8. Volume versus capacity comparison of German airports, for the unconstrained reference scenario, 2010



CAPACITY UTILISATION IN THE CAPACITY INFLUENCED SUPPLY AND MARKET SCENARIO 2010

Therefore, two additional—capacity influenced—scenarios have been written with the aim to reduce movements at the two most overloaded airports: the supply scenario and the market scenario. In the supply scenario,

there is an increase of the load factor and aircraft size—within plausible margins—on flights from and to Frankfurt and Düsseldorf. In the market scenario, there is also a change of airport choice for holiday travel—attractive offers of tourist flights from smaller airports in the catchment areas of these airports—and a close and successful co-operation of air and rail offering high speed rail services as alternative to short haul.

The measures applied cause a reduction of approximately 200,000 ATMs as a whole as compared to the reference scenario, of which about 45,000 ATMs are at Düsseldorf and about 100,000 ATMs are at Frankfurt. The reduction of movements in Düsseldorf is traced back mainly to the change in airport choice, and in Frankfurt to the substitution of short haul flights by high speed trains to and from Köln/Bonn, Stuttgart, and Düsseldorf. The reduced flight movement volumes are well below the values of the reference scenario for these airports but traffic loadings in the typical peak hour remain at or above the capacity level. The other four busy airports also remain near the capacity barrier of the runway system or exceed the hourly capacity further on (Figure 9). This means that the daily occurring traffic peaks can be dealt with only by tolerating problems in operations and tolerating severe delays to passengers and flights.

With the demand continuing to grow in the coming years—as has been described earlier—there is the question how the air traffic system in Germany can be handled in the future. Can the hub-and-spoke concept, as it is pursued today, be continued under circumstances where the traffic levels in general surpass those of today by about 50%?

Frankfurt, as the main hub in Germany, intends to build a fourth runway. The project approval procedure shall start this year; the new runway shall operate in 2006/07. In return for the capacity expansion, Frankfurt is prepared to trade in a night curfew. The new runway will bring the capacity of the runway system to about 120 movements per hour. It is supposed that after a short phase of free traffic conditions Frankfurt will again run to the capacity limit. Our forecast movements for 2010 already points to this fact.

Düsseldorf airport has a parallel—dependent—runway system with an estimated capacity of about 55 to 60 movements per hour. Today Düsseldorf is not allowed to use both runways without restrictions. There is an administrative regulation limiting the hourly movements to 38. But even if Düsseldorf should get the permission for an unrestricted operation, the airport will remain overloaded.

In our forecast, München was given a flight offer structure without any adaptation to bottlenecks. Meanwhile a spatial redistribution of hub-traffic has begun, and München attains the role of a second hub in Germany. Therefore, being nearly overloaded in the future scenarios already without the hub-function, the airport is forced to enlarge the capacity earlier than planned. München intends to build a third runway, however, has not yet

made such plans public. Regarding the duration of the administrative and legal process for obtaining a building permission in general, the start-up of the new runway seems to be in the long-term future.

Figure 9. Volume versus capacity comparison of German airports, for the capacity influenced market scenario, 2010

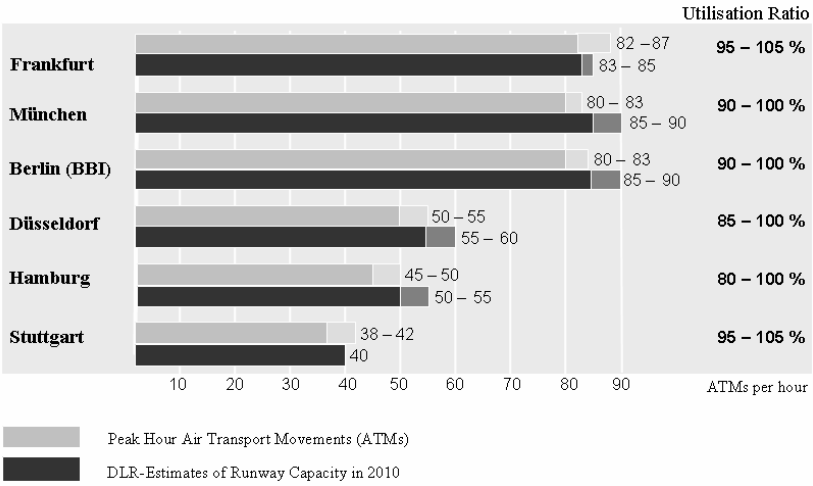
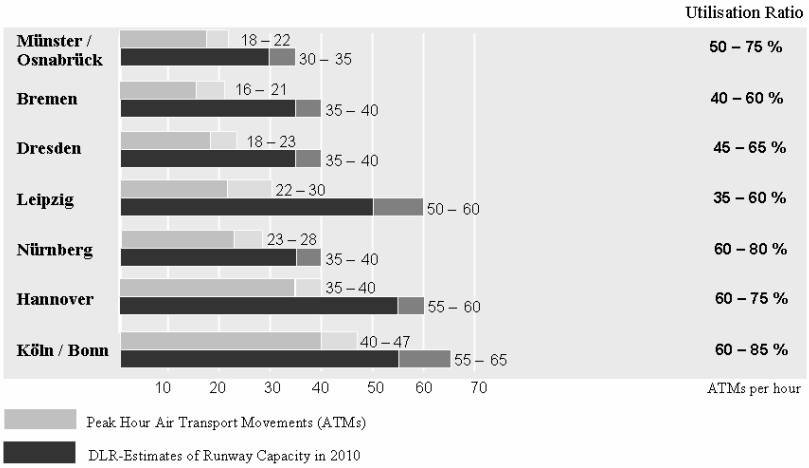


Figure 10. Volume versus capacity comparison of German international airports, in the unconstrained reference scenario, 2010



Until now, only the busiest airports in Germany are considered. But what happens with the other German airports. Are they able to provide the necessary capacity reserves?

In Figure 10, the utilisation of seven other international airports is shown for the unconstrained reference scenario. All these airports still have capacity reserves. Three of them—Köln/Bonn, Hannover, and Leipzig/Halle—have two or three runways with runway lengths which are qualified for aircraft used in intercontinental flights. Most of the countries in Europe and of the holiday regions in North Africa are reachable from the other four airports.

WOULD LOW COST CARRIERS EASE THE CONGESTION PROBLEM?

While the traffic stagnation and reduction since the year 2000 eased the current capacity situation at Frankfurt and Düsseldorf, forecasts of those institutions that are normally involved in the forecast task unanimously indicate a continuation of the former growth trend of air travel demand. As a result of the scenario dependent forecasts of traffic and traffic loadings at the German airports we have to retain that one-third of the international airports of Germany, which handle three-quarters of the total air traffic, will have no capacity reserves in the coming years in a situation of continued demand growth. Further adaptations of operations, like higher loading factors and greater seat capacity of flights and of airport infrastructure will be needed. And it seems that the ongoing pursuit of the hub-and-spoke concept cannot be continued like that in Germany if the hub airports are not in a position of enlarging their runway capacity substantially.

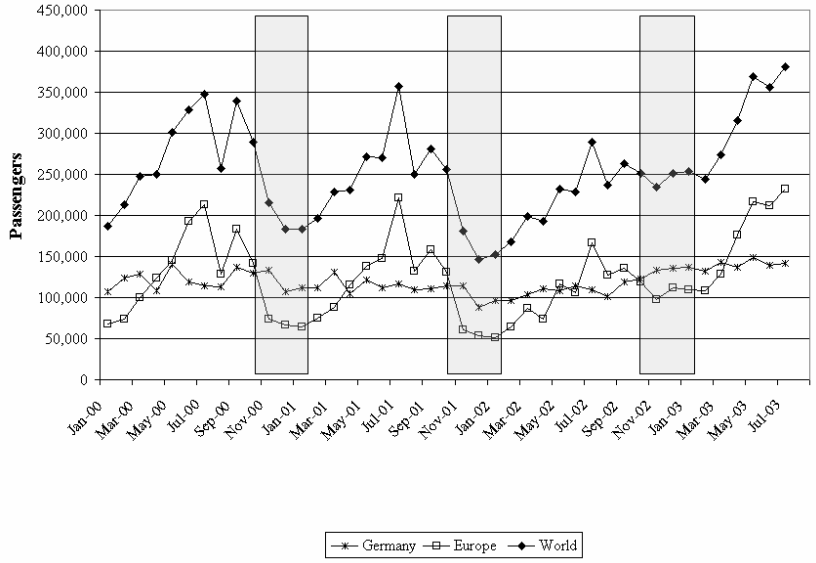
The situation of weak demand development has been used by low cost carriers to enter the German market and offer services from a few airports with great capacity surplus to destinations in Germany, like Berlin-Tegel in particular, and in Europe, like London-Stansted, Milan (Bergamo and Malpensa), Pisa, Florence, Rome, Barcelona and other destinations primarily in Italy and Spain. Ryanair has began a low fare business from Hahn airport in 1999, an airport, that had almost no traffic until 1999. In that year it had less than 100,000 passengers on scheduled services; and in 2002 it had about 1.4 million passengers, almost all of them on Ryanair services.

In autumn 2002 the new low cost carrier (LCC) German Wings started services from the well-established airport Köln/Bonn in a similar way as Ryanair has done before from the newcomer airport Hahn. Köln/Bonn is an airport with high capacity in the runway system, the terminal and parking facilities, with good surface access, and most of all, with a great catchment area reaching to the Rhine-Ruhr District. In December 2002, the start-up LCC Hapag Lloyd Express followed the Ryanair and German Wings

example and competed directly with German Wings on a number of traffic relations from Köln/Bonn.

Like in Hahn we can observe in Köln/Bonn a strong demand generation as a consequence of low fare offers of the LCCs. Ryanair has generated a travel volume of more than one million passengers within two years in Hahn and traffic development in Köln/Bonn shows similar generation effects (see Figure 11). The typical seasonal pattern of traffic can be seen for the years 2000 and 2001, with the sharp decline of traffic in October/November and the low traffic levels in winter, this pattern, however, is not repeated at the end of 2002 when the LCCs had started their business at Köln/Bonn. In the winter months of 2002/2003 traffic was about 100,000 passengers per month higher than in the preceding winter months. Assuming this trend continues over the year we can expect a demand generation of over one million passengers per year, like in Hahn.

Figure 11. Passengers per month from Köln/Bonn airport to sixteen international airports in Germany, Europe and the world



Source: *Monthly air transport statistics: 2000-2003.* (2003). Wiesbaden, Germany: Federal Statistical Office/

The most well known example of market stimulation of low fare services is the traffic development on the route London-to-Dublin, where Ryanair started services in 1986. Before that date traffic volume had been stable with about one million passengers per year. After the market entry of

Ryanair, passenger numbers doubled within 5 years and quadrupled within a period of 15 years. The generation was caused by a sharp price reduction from about BP 200—before to as low as BP 50—per round trip with Ryanair. There are sources giving the average yield of Ryanair services from Hahn to European destinations being in the order of 50 euros per leg.

There is evidence that LCCs have a great market potential and that the business model of traditional network carriers will not disappear—network carriers will continue to exist and operate world wide networks—but will serve a declining share of the total market (Binggeli, 2003; Franke, 2003; Tretheway, 2003). In the U.S. the market with the longest experience with LCCs, in particular Southwest, the market share of LCCs as measured in passenger volume is in the order of 20% to 25% whereas in Europe this share is much lower (around 5%), however, with a strong tendency to grow. According to estimates of Tretheway (2003), Bingelli (2003) and others, LCCs may achieve a market share in Europe of around 50% in the long run, this being combined with a strong market stimulation. At the same time we will observe a diversification of the full service network carriers, with the objective to capture a part of the LCC market.

The future business model in European air transportation may look like a diversified spectrum of airlines coming from traditional network carriers, operating in alliances; regional carriers, independent or affiliates of network carriers; tourism or charter carriers, and low cost carriers, in which network carriers concentrate on interconnected global and, in particular, intercontinental services (Ehmer, 2003). From network carriers outsourced carriers will take over the feeder function on heavy demand hub routes. Regional carriers continue to feed hub airports for the network carriers and serve small demand hub-by-pass routes. LCCs will serve more and more hub-by-pass domestic and direct European routes, thereby avoiding direct competition with hub carriers and congested airports. In addition, tourism carriers continuing their traditional holiday package services will offer seat-only services on tourist relations and partly compete with LCCs.

Given the traffic generation prospect of LCCs on the one hand and the airport bottleneck prospect on the other hand, will there be an ease of the capacity problem due to LCC operations? The answer is uncertain at this early stage of LCC market penetration in Europe, it seems, however, that LCCs will also in the future concentrate their services on airports with ample capacity, where they have freedom of getting slots as needed, have fast turn-around times and can possibly keep down airport fees due to the interest of the airport owner to attract business. They may face a problem in serving markets of hub and busy airports like Berlin-Tegel and Düsseldorf because of lack of available slots and lack of low airport fees and because of potential competition with other carriers, in particular network carriers.

We can assume therefore that LCCs will not aggravate the capacity problem, but will not contribute to alleviate this problem either. They will generate substantial demand, however, not on routes connected with airports with capacity problems. As such they may help to reduce the discrepancy of airport utilisation, but without a strong effect on taking away demand from hub airports. They may attract traffic which is handled today by congested airports without hub function, like Düsseldorf, if alleviator airports are located in the same region suited for LCC operations, like Mönchengladbach.

EXPECTATIONS: CONGESTION OF EXPANSION

If one would add up the runways of the international and selected regional airports of Germany (about 40 runways) to determine the total capacity and compare the total ATM volume with capacity the result would be a great surplus of capacity. Such a result is of theoretical value only, since runway capacity is needed near the areas of demand generation and attraction. We have shown that at present Frankfurt—the busiest hub airport—and Düsseldorf—a busy airport with primarily O-D traffic—are working at capacity level and cannot satisfy additional demand from traffic which has to use alternative airports, but would prefer these airports if possible. Lufthansa, the hub operator in Frankfurt, is diverting hub services to München in an attempt to interconnect their market with the global alliance network via two airports.

While the traffic stagnation and reduction since the year 2000 ease the current bottleneck situation at Frankfurt and Düsseldorf, forecasts indicate a continuation of the former growth trend of air travel demand. A prime result of the scenario dependent traffic forecasts is that one-third of the international airports of Germany, which handle three-quarters of the total air traffic, will have no capacity reserves in the coming years in a situation of continued demand growth. In other words, the six busiest airports of Germany will not have sufficient capacity to handle the future demand if no additional runways are built. As the market scenario has shown there are means available to airlines to adapt to the shortage of capacity, for instance by operating bigger aircraft with higher load factors, these measures can be applied, however, only to a certain degree. The reduction of flight movements in the market scenario as compared with the reference scenario does not yield operating conditions which can be regarded satisfactory. Daily occurring traffic peaks will prevail, with intolerable delays for passengers and flights.

Two of the six overloaded airports are Frankfurt and München, which are already today used as hub airports. In case of no capacity enlargement, it is quite clear that the hub-and-spoke concept as pursued so far cannot

continue like that and will have to be changed in the direction of a network with more direct connections. Charter and tourism carriers and LLCs follow the concept of direct services, more or less, but traditional network carriers still prefer the realization of connectivity between networks of alliance members and of intra-airline O-D relations through hub-and-spoke operations.

Of the six new runways needed, in addition to those existing at the overloaded airports, two are likely to be realized: in Frankfurt and in München. For the other non-hub airports, especially in Düsseldorf, no public plans exist to enhance runway capacity. This is partly caused by the fact that airport owners—which are often public entities—do not have the means to overcome the resistance of the public living in the surroundings of the airport against new airport infrastructure. Those living near the airport are afraid of the negative effects of aircraft operations, like noise and emissions. Airport expansion is often not an economic problem but an environmental one. It may be, however, that new slot allocation procedures based on trading would alleviate the peak traffic problem in general by diverting traffic to less congested airports and thus, take care of a spreading of services over the network.

Another way of air supply spreading has been taken up by LCCs already by choosing non-congested airports for their predominantly direct service business. In doing so, they pull away some demand from network carriers and thus from the hub-and-spoke network; their main effect is, however, to serve with low fares a public which did not participate in flying normal scheduled services (with high prices) before. Southwest does not claim to compete intensively with other airlines—they leave the market when Southwest enters the market—but with the private car. In balance it seems that LCCs will not contribute to alleviate the capacity problem of the hub and other busy airports, but will give non-congested airports a chance to augment their business substantially.

If the objective of transport policy remains oriented towards satisfying demand then enlargements of capacity at the most important airports of Germany will have to be realized. With air demand growing in the order of 50% to 100% in the long run it is rather evident that additional runway capacity is needed, in particular in the Düsseldorf and Frankfurt area, however, additional measures like supply spreading to other non-congested airports through new business models of carriers are an essential remedy of the capacity crisis at some busy airports, too. It is in the same context that there are many airports with ample capacity which would prefer to increase their market shares rather than to loose them as has been the case in the past.

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