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*Full Research Papers* should contain original research not previously published elsewhere. They should normally be between 4,000 and 7,000 words although shorter or lengthier articles could be considered for publication if they are of merit. The first page of the papers should contain the title and the authors' affiliations, contact details and brief vitae (of about 50 words). Regarding the following pages, papers should generally have the following structure: a) title, abstract (of about 150 words) and six keywords, b) introduction, c) literature review, d) theoretical and/or empirical contribution, e) summary and conclusions, f) acknowledgements, g) references and h) appendices. Tables, figures and illustrations should be included within the text (not at the end), bear a title and be numbered consecutively. Regarding the referencing style, standard academic format should be consistently followed. Examples are given below:

- Airbus (2003), *Global Market Forecasts 2003-2022*, Toulouse: Airbus.
- Fragoudaki, A., Keramianakis, M. and Jancovich, S. (2005) The Greek PSO Experience. *4<sup>th</sup> International Forum on Air Transport in Remoter Regions*. Stockholm, May 24-26.
- Forsyth P. (2002a), 'Privatization and Regulation of Australian and New Zealand Airports', *Journal of Air Transport Management*, 8, 19-28.
- Papatheodorou, A. (2008) The Impact of Civil Aviation Regimes on Leisure Market. In Graham, A., Papatheodorou, A. and Forsyth, P. (ed) *Aviation and Tourism: Implications for Leisure Travel*, Aldershot: Ashgate, 49-57.
- Skycontrol (2007) *easyJet welcomes European Commission's decision to limit PSO abuse in Italy*. 23<sup>rd</sup> April. Available from: <http://www.skycontrol.net/airlines/easyjet-welcomes-european-commissions-decision-to-limit-psy-abuse-in-italy/> (accessed on 22/08/2008).

*Conference Reports* should be between 1,000 and 1,500 words. They should provide factual information (e.g. conference venue, details of the conference organizers), present the various programme sessions and summarize the key research findings.

*Book Reviews* should be between 1,000 and 1,500 words. They should provide factual information (e.g. book publisher, number of pages and ISBN, price on the publisher's website) and critically discuss the contents of a book mainly in terms of its strengths and weaknesses.

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

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## Editorial

This issue of the *Journal of Air Transport Studies* includes four papers.

Lechmann and Niemeier provide a critical overview of the air transport literature on economies of scale and scope concluding that the majority of studies are problematic with respect to the definition of “output”, the treatment of capital and the exclusion of land side activities. In another paper, Fatokun reviews the current practices in airport security concluding that there are reactive, expensive and inefficient in some areas based on a “one-size-fits-all” principle. The paper argues in favour of pro-activeness based on passenger differentiation.

In the following contribution, Harasani simulates the evaluation and selection of an aircraft fleet for a proposed airline located in Madniah, Saudi Arabia, to operate across an assumed network that includes both local and international destinations. The paper suggests that the EMB170 aircraft would be the best choice for the proposed airline. Finally, Burbidge studies the impact of climate change on aviation making five key recommendations on how to develop a framework of cost-effective climate resilience within the sector: climate change is an issue of risk management and early action is the key to cost-effective mitigation of those risks.

May we take this opportunity to thank all our authors and referees for their support in publishing this eighth issue of the Journal. Our continuing partnership with Air Transport News in conjunction with the open access character of the journal aim at ensuring that JATS can get a significant exposure to the academic and business audience and raise its profile accordingly. Enjoy reading!

*Dr Andreas Papatheodorou, Editor-in-Chief*

*Dr Kostas Iatrou, Associate Editor*

*Dr Zheng Lei, Assistant Editor*



# ECONOMIES OF SCALE AND SCOPE OF AIRPORTS – A CRITICAL SURVEY

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## ABSTRACT

The question whether airports are natural monopolies has increasingly become an issue in studies on regulation, deregulation and privatization of airports. In particular it was questioned whether airports have market power at all and if this is due to economies of scale and scope. This paper provides an overview of studies on economies of scale and scope. It critically evaluates the method of data gathering during the studies and the resulting information uncovers some drawbacks of the studies and the data gathering process. It reaches the conclusion that the most studies on economies of scale are problematic in regard to the definition of "output", the treatment of capital and the exclusion of land side activities. Economies of scope have only been researched in the most recent studies. The study illustrates that the non-aviation business should be considered in more detail.

Keywords: Economies of scale and scope, DEA, econometric estimations cost functions, natural monopoly

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## 1. INTRODUCTION

The nature and breadth of economies of scale and scope are essential for airport economics, management and policy. Are airports public utilities because economies of scale and scope lead to a natural monopoly which needs to be publicly owned or regulated? Should airports (of which size) be subsidized to cover their high fixed costs? How many airports should there be in a region on narrow economic ground abstracting from environmental externalities? Will a region like Berlin gain if it closes two of its three airports and concentrate its traffic on one? Will new airports enter the market or does this not happen because of scale economies or because of planning restrictions? Is terminal competition feasible because economies of scope are limited? Can freight be separated from passenger traffic and the latter are split up in national and international traffic without any economic costs? Is the tendency to develop commercial activities only driven by demand complementarities or are there cost complementarities to be reaped as well? This list of questions can easily be extended, but it is already obvious that the nature and scope of economies of scale and scope are essential for all important problems of governance, regulation, planning, pricing and management of airports.

The importance is, however, negatively related to what textbooks and even a number of benchmarking studies say about these economies. The standard view (Button and Stough, 2000, Graham, 2008, Oum et. al. 2006, Doganis, 1992) has been that economies of scale run out at a level of three or five million passengers. This is surprisingly low as it would imply that there are hardly any barriers to entry other than legal and planning restrictions. Market entry could occur at regions serving six to ten million passengers so that, for example, most European airports face potential competition. Given the expected growth rates we would expect in the near future a wave of new entrants leading to a situation that in most cities and regions two or more airports will compete intensively making regulation obsolete. The EU directive on charges should then revert its threshold, that is, instead of regulating airports of more than five million it should regulate small regional airports in rural areas.

In this paper we challenge the standard view by critically reviewing the existing literature. We ask at what output level run out economies of scale? Do diseconomies occur at all? Do economies of scope exist and if so between which activities?

In reviewing the literature we will analyze how the studies model the airport. This is particularly important as the production process has changed over the period of research

which begins in 1973. Researchers such as Graham (2008) have argued that the business focus of the airport has changed in the last decades. The non-aviation business including shopping centers and the use of the airport facilities for conferences etc. has grown to such a scale that today for many airports commercial revenues make up to 50 percent of the total revenue.

This paper is organized as follows: the first section we will concisely explain the concept of economies of scale and scope. In section two, we will describe the airport production process highlighting structural changes and inspect the deriving key processes which studies show should be accounted for in each case. In section 3, we will analyze several studies dedicated to the measurement of economies of scale and scope at the operational level of an airport. We will highlight potential drawbacks, differences and similarities concerning the definition of output, input, and costs of an airport. Finally, in the concluding section, we will sum up our findings and suggest areas of further research.

## **2. ECONOMIES OF SCALE AND SCOPE**

Right from the outset it is important to distinguish between short run and long run economies of scale and scope as the paper is about the latter. In the short run at least one factor is fixed so that the firm cannot adjust as perfectly its production to changes in demand and other factors as the firm can in the long run. In the short run increasing demand might lead to economies of density, which is to decreasing average costs due to more intense capacity utilization. These have been estimated for airports by Gillen and Lall (1997) and by Pels et.al. (2010). Also, diseconomies resulting from airport congestion belong to the short-run theory of production (Janic and Stough, 2003). Thus short run decreasing average costs are caused by sharing fixed costs while long run costs are caused by indivisibilities. Economies of scope, on the other hand, can be obtained when the joint production of two or more goods saves cost compared to a separated production.

The differentiation between short-run and long-run is not linked to a certain time period but related to the existence of fixed input factors. In the short-run some kind of input factor is fixed and thus cannot easily be changed without investment. In the long-run every input factor is variable and no fixed factors exist (Nicholson and Snyder, 2007). Viner (1932) investigated the relationship between short-run and long-run average cost curves and showed that the long-run cost curve builds an envelope around several short-run cost

curves. This indicates that the long-run average cost curve is tangential to the short-run average cost curves. Doganis (1992) applied this concept to the airport industry. Terminals and runways are in the short-run fixed input factors, thus cannot easily be changed. Increasing the number of runways the short-run cost curve shifts to the right, indicating lower average cost. In the long-run, when all factors are variable Doganis (op.cit.) predicted that in the case of an L-shaped cost curve the long-run cost curve is always tangential at the minimum of the short-run cost curve.

### *2.1 Indivisibility and its Results*

The theory of perfect competition implies the existence of an atomistic market structure, with many suppliers and demanders who each have a relatively small market share. This includes a functioning market with infinite divisibility of input factors. However, many markets are marked by a concentration on the supply side, sometimes even in its extreme form as a monopoly (Fritsch et al., 2003). This can lead to market failure and welfare losses. The market failure can result from so called indivisibilities of input-factors. The indivisibility can result from resources whose characteristics and functions can be varied only in limited steps. "A commodity is indivisible if it has a minimum size below which it is unavailable without a significant quality change" defines Baumol (1987, p.793). Runways might be an example of such an indivisibility and perhaps also terminals. Such indivisibilities might cause sub-additive cost-functions, decreasing average costs (economies of scale), and increasing returns to scale.

*Returns to scale* show the relation between a proportional change of all inputs and the related change in output. This means that the ratio between all input-factors remain constant. They can be differentiated into three types of returns to scale constant returns to scale, decreasing returns to scale and increasing returns to scale. Constant returns to scale imply that a change in the quantity of all input factors leads to an equal change in output, decreasing returns to scale lead to a under proportional change in output and increasing returns to scale mean an over proportional output change (Eatwell, 1987). If we consider constant input prices, an over proportional output change would also imply decreasing average costs. Therefore one can conclude that increasing returns to scale is a special case of economies of scale, decreasing average costs. The concept of economies of scale is broader since it as opposition to returns to scale also includes the possibility of a change in the ratio of input-factors (Fritsch et al., 2003).

*Economies of scale* exist, when the average total costs (ATC, fixed and variable costs per unit of output) decline over a certain range of increasing output (Silvestre, 1987). In the perfect competitive model the average total cost curve (the relationship between average total costs and output) is U-shaped at least in the short run, which indicates that the average total costs decline over a certain range of increasing output and increase again after they reached their minimum (Besanko et al., 2004). This minimum point of the average total cost is referred to as optimum point of scale (Pratten, 1971).

The downward sloping part of the short-run ATC curve can for example be explained by the fact that fixed costs, which are by nature unrelated to the output of the company are spread over a wider range of produced goods if output increases. These fixed costs can be related to airport terminals and facilities, insurance, costs for machinery like conveyer belts, stairways and so on. The upward sloping part of the short-run ATC curve is caused by the fact, e.g. that the company reaches its capacity limit and has to enlarge its production facilities like runways and terminals at an airport, to produce more goods. Congestion increases the short run costs and in addition the company “encounters bureaucratic and agency problems” (Besanko et al., 2004, p. 74). If we consider this U-shaped cost curve as given for each industry one would conclude that small and large firms have equally high average costs for producing one product.

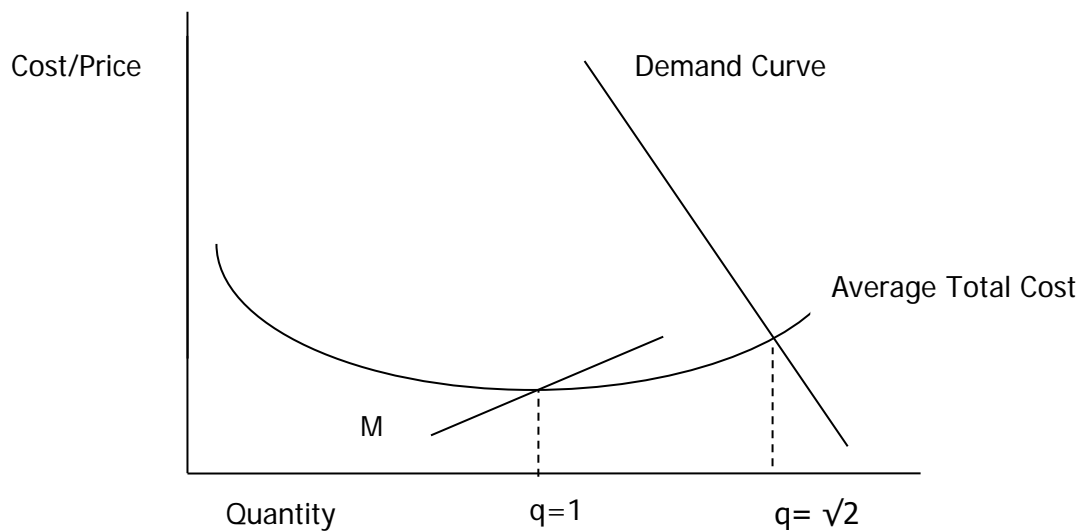
A necessary condition for the existence of a natural monopoly is a *Sub-additive cost-function*. This relates to the fact that the production of the whole quantity of a good is lower than the sum of the total costs of a partial production of that quantity. In other words if  $TC(X^M)$  are the total costs of the whole quantity of good  $X$ , and  $X^m$  ( $m= 1, 2, 3...n$ ) are the single quantities of a partial production (Baumol et al., 1982 and Frank, 1969). In this case sub-additivity of the cost-function indicates

$$TC(X^M) < TC(X^1) + TC(X^2) + \dots + TC(X^n)$$

This can also imply the existence of decreasing average costs over the range of the expanding output. Although economies of scale in the range of the quantity demanded are a sufficient condition for a natural monopoly, it is not a necessary condition. Fig. 1 shows that a natural monopoly can exist even beyond the minimum efficient scale when average costs rise again. As long as the quantity demanded at the intersect of the demand curve and the average total cost curve is less than double the amount of the minimum efficient scale it would be less costly if the supply of the good would be produced by one firm (Joskow, 2007). Such a constellation is called weak natural monopoly to differentiate it from a strong

natural monopoly with decreasing average costs (Church and Ware, 2000, p. 786). As airport investment is a relation specific investment fixed costs have the character of sunk costs so that a natural monopoly is not contestable (for a detailed discussion of sunk costs of airports see Wolf, 2005).

**Figure 1 - Sub-Additive Cost Function and Increasing Average Cost**



Source: Joskow, 2006, p. 10

The three concepts are interrelated, since they can partially explain the sources for indivisibility of input-factors, whereby they build upon each other. Increasing returns to scale are very strict in their assumption of a fixed proportion of input-factors, indicating a special case of economies of scale. Economies of scale relate to decreasing average cost over an increasing range of output, whereby the combination of input-factors is allowed to change. The concept of sub-additivity of cost-functions offers a complete capture of all relevant cases of indivisibilities of commodities. It can explain these indivisibilities even if the average total cost are not declining over the complete range of increasing output (Fritsch et al., 2003).

### *2.2 Economies of Scope*

While economies of scale are linked to decreasing costs over a range of increasing output, economies of scope describe the situation where it is feasible for the company to produce a variety of products, since this will reduce its total costs. This implies that it is cheaper to produce these products in a single company instead of producing each one separately (Panzar and Willig, 1981):

$$TC(Q_1, Q_2) < TC(Q_1) + TC(Q_2)$$

Whereby  $TC(Q_1, Q_2)$  is equal to the total cost of a conjoint production of products  $Q_1$  and product  $Q_2$ .  $TC(Q_1)$  and  $TC(Q_2)$  are the total cost for each product in a separated production process.

There can be two reasons for economies of scope. First use of a sharable input or second the production of a by-product. If we consider a two-product case, there can be the possibility that these two products use a common input, like production/research facility or heating and electricity generators (Fritsch et al., 2003). Examples at an airport would be a terminal used for domestic passengers and international passengers or a conveyer belt for luggage and cargo. Also human-capital e.g. workers who are able to carry out several working steps in the production process of more than one product can be a reason for the existence of economies of scope.

The second possibility is the appearance of a by-product in the production process of the main product, whereby the most common examples are mutton and wool (Panzar and Willig, 1981). Transferred to the airport business, one could say that the passenger handling is the main product and as a by-product the airport provides cargo and luggage handling, while handling the passenger traffic.

### **3. THE AIRPORT BUSINESS**

Since the 1970s the production process of airports has changed substantially. The range of airport business has broadened. Doganis (1992) differentiates between "essential operational services and facilities, traffic-handling services and commercial activities (p.7)". While the basic inputs like runway and outputs (passenger, movements and freight) of the airport barely changed over the last decades, other inputs and outputs have changed indeed. Especially the non-aviation business has increased its importance for the airport business from 41 % in 1983 and has reached at some airports already up to 50 percent of the revenue (Graham, 2008). The focus shifted to the commercialization of the airport business and the expansion of commercial non-aviation activities (Freathy, 2004). Fuerst et al., (2011) argue that today's airports are multiproduct companies serving as consumer temples and wellness oases for the wealthy business travelers as well as service providers for the airlines.

Outsourcing and technological progress, e.g. online check-in, self-baggage handling and other forms of self-service has transformed the airport business (Chang and Yang, 2008).

Airports are characterized by different degrees of outsourcing. While for example German airports offer ground handling services, UK airports have relied on third party providers. Although EU liberalized ground handling German airports have not changed their business model, but airports in a number of other countries have (Templin, 2010).

Estimating costs of airports with different models involves the use of models. These models reduce the complexity of real business. It is not necessary and sensible to capture all the details and complexities of the airport business, but the changing nature and the increased complexity can lead to problems. Focusing exclusively on the so called core business of airports by abstracting from commercial activities involves allocating common costs between separate business areas which is difficult to obtain. It is self-evident that in a multi-product firm the processes are interrelated and that the overall efficiency depends on how the processes are managed.

#### **4. SURVEYING THE APPLICATION OF ECONOMIES OF SCALE AND SCOPE TO THE AIRPORT INDUSTRY**

We have now analyzed the basic concept of economies of scale, thus giving us the knowledge to evaluate the application to the airport industry. We have seen that the airport business has expanded from a "field" for landing and departure of an airplane to a diversified multi-business; including ramp and traffic handling, management of events and other commercial activities not directly related to the aviation business. It can be expected, that the studies analyzed include some factors concerning the different business activities of the airports and thus the diversification.

There have been several studies concerning the examination of economies of scale in the airport industry. Although these studies are concerned with the same industry they come to very different conclusions. The results range from no economies of scale at all, up to the existence of economies of scale until a traffic volume of 3, 20 or even 90 million passengers or that they do not exhaust at any number of passengers or work load unit<sup>1</sup> (WLU). The next section will look at several studies by examining the data they used e.g. which airports, how many airports and over which period they did observe. A further criterion will be the

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<sup>1</sup> A work load unit (WLU) is equal to one passenger or 100kg of freight



methodology they used in their study, which will be explored. Under these premises the results of the studies will be evaluated. Due to this it will be possible to assess the strength and weaknesses of each and maybe give advice for improvements.

#### *4.1 Application of DEA on the Economic Performance of Airports*

Gillen and Lall (1997) started to use DEA to measure the productivity of airports, whereby they focused on the economies of density. Thus not strictly concerned with economies of scale it is a good starting point for the analysis of the airport economics. They separated between airside activities e.g. the gate capacity and the terminal side. Through this they aimed to analyze the strategic options for airport managers to increase the efficiency in the short run. Thereby they indicated that several parameters, e.g. the increase of number of gates including the management of them, in the reach of the airports management can have a substantial impact on the airports efficiency.

Similar results concerning the short-run costs can be found in Pels et al. (2010). Like Gillen and Lall their study used DEA as a method to depict the occurrence of economies of density of 36 international airports. Hereby is the most significant cost driver the number of handled passengers whereby they concluded a strong influence of the fraction of international passenger.

The Gillen and Lall study indicated that economies of density exist at the operation of an airport thus leading to the question whether or not decreasing average costs remain in the long term and thus economies of scale exist. As seen in Table 1 there have been several studies concerned with the application of Data Envelopment Analysis<sup>2</sup> on the airport industry.

One of the first who applied this relative new methodology were Pels et al. (2003). Their sample consists of 33 European airports and they used a data set containing two years of observation. Pels et al. (op.cit.) used the airport's surface area (ha), number of aircraft parking positions at the terminal, number of remote aircraft parking positions, number of runways and number of runway crossings as input factors to measure air traffic movements

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<sup>2</sup>DEA is a non-parametric estimation method introduced by Charnes et al. (1978), which estimates on the basis of empirical data the practical feasible terms of efficiency. In contrast to econometric estimations it only considers realizable solutions and needs no specification of the production or cost function. Banker et al. (1984) developed this methodology further to incorporate the possibility of varying returns to scale.

(ATM). ATM served also as an indirect input for air passenger movements (APM), whereby the further input factors for APM were number of check-in desks and number of baggage claim units. With their estimations Pels et al. (op.cit.) reached the conclusion that an average airport (12,5 Million PAX<sup>3</sup> and 150.000 ATM) exhibit constant returns to scale in ATM and increasing returns to scale in APM. This indicates that there are no economies of scale in the operation of a runway but that they can be realized in the terminal operation. Although the study is consistent, it has some major drawbacks. It does not include the labor inputs of the airport even though they make up a high proportion of the total inputs of airport operations. Bazargan and Vasigh (2003) analyzed 45 US airports, whereby they used a data set for the period of 1996-2000. As output measures they used PAX, annual air carrier movements as well as other air traffic movements. Thereby they employed operating expenses, non-operating expenses, number of runways and number of gates as input factors. As an outcome of their study they reach the conclusion that small airports are more efficient than large airports, whereby they differentiate the airports according to the percentage of national enplaned passengers<sup>4</sup>.

Vogel (2005) investigated the financial performance of airport thus using different input and output factors than other related studies. He applied DEA by using total revenue as output and total expenses including depreciation as input of the airport. Although no further information is given, and even though he is just concerned with the financial aspects of the operation of an airport, he comes to the conclusion, that economies of scale exist up to four million PAX and that beyond this point diseconomies of scale set in. Additional information would be helpful in order to evaluate his calculations and to compare them with other studies.

One of the latest studies dealing with this issue is from Ablanedo-Rosas and Gemoets (2010). They analyzed the Mexican airport industry with a data set of 37 airports. As output they used Aircraft Movement, PAX and tons of cargo and number of passengers per hour and number of operations per hour as input factors. Although the study is more concerned with the economic efficiency of Mexican airports it also tested via a Wilcoxon (1945) test<sup>5</sup> the existence of economies of scale. Thereby, their estimations reach the conclusion that there

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<sup>3</sup> PAX – Number of Passengers

<sup>4</sup> large > 1 %, medium= 0.25 – 0.99 %, small = 0.05-0.24%

<sup>5</sup>The Wilcoxon Test is a non-parametric test on the comparison of two related observation samples

are differences between the economic efficiency of large<sup>6</sup> and small airport, thus indicating the existence of economies of scale. The largest airport in the sample has an output of 12 million PAX.

All DEA studies have in common that they draw conclusions about economies of scale from the estimation of returns to scale. Although not per se false this indication is incomplete. What as Fritsch et al (2003) has described in his study are increasing returns to scale, a special case of, and not, the same as economies of scale. This implies that there is the possibility that economies of scale exist although there are no increasing returns to scale. This would indicate that estimations of economies of scale based on returns to scale are incomplete.

#### *4.2 Application of Econometric Estimations on the Airport Industry*

Two of the first who applied econometric estimations for calculating the cost structure of airports were Doganis and Thompson (1974). Doganis and Thompson analyzed the data of 18 UK airports over a two year period from 1969-1970. They assumed a Cobb-Douglas cost curve, using WLU as output measure. To account for different activities of airport operation they categorized the cost into total, capital, maintenance, labor, administrative and operating cost. In the process, they also investigated the influence of a recent development program introduced by the British Government and the operation of air traffic control on airport costs. The study concluded that economies of scale exist up to three million WLU. Due to the drawbacks of a Cobb-Douglas Cost function their assumptions were very restrictive and thus not very meaningful. In addition, as indicated by Tolofari et al. (1990), their separation of different cost types can lead to estimation disruptions and as a result to a false cost curve. Tolofari et al. (1990) criticized Doganis and Thompson (1973) and eliminated their faults. They applied a translog cost function to account for more flexibility. Like Doganis and Thompson (1973) they used WLU as an output measure, whereby they indicated labor, equipment, residual factors and capital stock as the inputs of an airport. Further variables include PAX per ATM, fraction of international passengers from overall passengers, percentage of used terminal capacity, and trends over time. They analyzed the data from seven BAA airports for the period from 1975-1987.

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<sup>6</sup> Large= more than 1 million Pax or Cargo tons

**Table 1 - Compilation of Studies using DEA for analyzing Economies of scale**

Author	TimeFrame	Sample size	Output measure	Input measure	Economies of scale
Pels et al. (2003)	1995-1997	33 European Airports	APM, ATM	Inputs for ATM: Airport's surface area (ha), No. of aircraft parking positions at the terminal. No. of remote aircraft parking positions. Nr of runways, No. of runway crossing Inputs for APM: ATM, number of check-in desks and number of baggage claim units	constant returns to scale in ATM and increasing returns to scale in APM up to 12.5 million PAX
Bazargan and Vasigh (2003)	1996-2000	45 US Commercial Airports	PAX, Air Carriers annual operation, Other aircraft movements	Operating expenses, non-operating expenses, No. of runways, No. of gates	Small airports(0,05 – 0,24% of national enplaned passengers) are more efficient than large airports(>1% of national enplaned passengers)
Vogel (2005)	1990-1999	35 European Airports	Total revenue	Total cost including depreciation	Economies of scale up to four million PAX and diseconomies of scale beyond
Ablanedo-Rosas and Gemoets (2010)	Not published	37 Mexican Airports	Aircraft Movement, PAX, tons of cargo	No. of passengers per hour, No. of operations per hour	Only four airports are scale efficient; testing for economies of scale via Wilcoxon test, which rejected the hypothesis, that large airports (>one million PAX or Cargo tons) are equally efficient than small airports. The largest airport has 12 million PAX

Source: Own research and investigation

This small sample of airports is also the major drawback of the study. They estimated that economies of scale exist up to 20.3 million WLU, but London Heathrow, with the highest volume of 38.2 Mio WLU over the observed period was the only airport in their sample which reached this size. The second biggest airport included in their sample, Gatwick reached only a volume of 18.5 million WLU. This leaves room for discussion about the range of the cost curve beyond this point and thus their result cannot be generalized.

In 1995 Doganis et al. analyzed the data of 25 European Airports from 1993. They chose, like the studies mentioned above, WLU as physical output measure and in addition value added<sup>9</sup> as a financial output measure. To account for different cost for domestic respectively international passengers, they differentiated between them. They divided their measured input factors in labor and capital, whereby the input factor labor consists of full-time equivalent, employee wages and salaries, and capital of capital charges including depreciation and interest rates and asset values. In their study Doganis et al. (1995) differentiated between three different regions where the airport was located, Northern Europe, Southern Europe and United Kingdom(UK)/Ireland. They found that at Southern European airports as well as UK/Irish airports Economies of Scale exist up to five million WLU and that they are not relevant at Northern European airports.

Main et al. (2003) included two different data sets in their study and thus reached two different conclusions. For both data sets they applied a Cobb-Douglas cost function. The first data set was provided by the Centre for Regulated Industries (CRI) and consisted of 27 UK airports for the period of 1988-1989. Since some airport data were incomplete they only included 25 airports in their measurement of WLU and 26 airports in measuring PAX. As input factors the study used price of staff, price of other costs, passengers per ATM, the percentage of international passengers and total assets. Concerning the operating costs Main et al. (op.cit.) differentiate between including and excluding of depreciation. They first calculated the short run cost curve and then derived the long run average cost curve by including operating cost, staff cost, depreciation and eight percent of the total assets as opportunity costs for capital. The study reached the conclusion that economies of scale are highly relevant up to four million PAX and five Million WLU and exist up to 64 Million PAX and 80 Million WLU.

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<sup>9</sup> Value added= total revenue – costs of intermediate inputs, thus it excludes costs which cannot influenced by management

As Table 2 shows the information consisted of the second data set used by Main et al. (2003), which was provided by the Transport Research Laboratory (TRL) of 44 international airports for a period from 1998-2001. Though not all variables were included for every airport they excluded all "airport groups and Hong Kong, which was a clear outlier" (Main et al, 2003, p.46). To account for the internationality of the data set, the currencies were converted into SDR<sup>10</sup>. They used the same input for the CRI data set but measured only the WLU as output. As for the CRI study, they first calculated the short run total cost curve. To reach the long run average cost they added operating costs with an eight percent interest rate and divided the sum by WLU. Thereby they estimated that clear economies of scale exist up to 90 million WLU. Main et al. (op.cit., p.47) admit that their study has some limitations, in particular the assumptions that "all airports operate with the optimal amount of capital with no economies of density available. This is unlikely to be true and so the true LAC curve may be lower than the estimated curve".

In 2005, Jeong composed a study of the operating costs of an airport, whereby he applied a translog cost function<sup>11</sup>, which was proposed by Tolofari et al.(1990). He analyzed the 2003 data of 94 US airports and found that economies of scale exist up to 2.5 Million PAX or three Million WLU. The study indicates PAX and WLU as the output of an airport but also creates a so called output index. This output index consists of PAX, number of aircraft movements and non-aviation revenue. Labor and other expenditures like operating and soft costs which, for example, includes contractual services. Jeong (2005) focused on US airports because "there is relative uniformity in the managerial and regulatory structure across most U.S. airports" (p.4) due to the fact, that they are all governed by the Department of Transportation and the Federal Aviation Administration. This implies one of the major drawbacks of international studies. They often do not take into consideration the differences in accounting practices across countries and thus created a false picture of the cost structure.

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<sup>10</sup> SDR - *Special Drawing Right*, a factitious currency implemented by the IMF in 1969 (Stock,1972)

<sup>11</sup> Transcendental logarithm (translog) cost functions in opposition to the commonly used Cobb-Douglas cost function which predicts an elasticity of input factor substitution of one (McCarthy, 2001), implies no fixed input factor relation at all. Thus the impeded restriction of the Cobb-Douglas function which can lead to statistical distortions in the estimations can be circumvented (Tolofari et al., 1990).

**Table 2 - Compilation of studies using econometric estimation for the examination of Economies of scale**

Author	Timeframe	Sample size	Output measure	Input measure	Economies of scale
Doganis and Thompson (1973)	1969-1970	18 UK Airports	WLU	Total, capital, maintenance, labor, administrative and operating cost	Economies of scale up to 3 million WLU
Tolofari et al. (1990)	1975-1987	7 BAA Airports	WLU	Labor, Equipment, residual factors, Capital	Economies of Scale exist up to 20.3 million WLU
Doganis et al. (1995)	1993	25 European Airports	WLU, Value added as financial measure	Labor Capital	Differentiation between Northern Europe(NE), Southern Europe(SE) and UK/Irish(UK) NE: No economies of scale exist SE & UK: Economies of scale up to 5 million WLU
Main et al. (2003)	1988-1989	27 UK Airports	WLU and PAX	Operating costs, price of staff, total assets	Strong economies of scale up to 4 million PAX and 5 million WLU Mild economies of scale up to 64 Mio PAX and 80 million WLU
Main et al. (2003)	1998-2000	44 International Airports	WLU and PAX	Operating costs, price of staff, total assets, excluding of non-core activities	Economies of scale up to 90 million WLU
Jeong (2005)	2003	94 US Airports	WLU, PAX and output index	Labor and other expenditures (operating and soft cost incl. contractual services)	Economies of scale up to 2.5 million PAX or 3 million WLU
Martin and Voltes-Dorta (2008)	1991-2005	41 International Airports	WLU and ATM	Prices of capital, labor and materials	Economies of scale are not exhausted at any level of output yet reached (83 million PAX)
Martin and Voltes-Dorta (2011)	1992-2008	161 International Airports	Domestic and international PAX, Commercial ATM, Commercial Revenue, Tons of cargo	labor, material and capital costs, terminal floor area, warehouse area, runway length, number of gates check-in desks and full-time equivalent employees	Economies of scale are not exhausted at any level of output yet reached (90 million PAX). Economies of scope between domestic and international traffic and aviation and non-aviation business activities

Source: Own research and investigation

One of the latest studies concerning the econometric estimation of economies of scale at airports is from Martin and Voltes-Dorta (2008). They analyzed the data of 41 international airports from North America, Europe, Asia and Australia for the period of 1991 to 2005. For their calculations they applied a single as well as a multi-product translog long-run cost function and used WLU and ATM as outputs. In addition the study material indicates capital and labor as inputs but exclude air traffic management cost. They transferred the prices of these three input factors into 2005 power purchasing parities (PPP). Martin and Voltes-Dorta (2008) come to the conclusion that economies of scale exist and are not exhausted at any level of output of their sample which includes airports up to the size of 83 million PAX.

The latest study related to the econometric estimation of airports cost function is provided by Martin and Voltes-Dorta (2011). It is one of the few studies including the diversification of the airport business. In their multi-product translog long-run cost function they constructed an output-index, which included the differentiation between domestic and international passengers, commercial ATM as well as tons of cargo and commercial non-aviation revenues. As their input factor they combined the financial factors of labor, material and capital costs with the physical inputs of terminal floor and warehouse area, runway length, number of gates as well as check-in desks and full-time equivalent employees and total landed MTOW<sup>12</sup>. With their data sample of 161 airports over the period of 1992 to 2008 they come to the conclusion that increasing returns to scale exist and are not exhausted at any level, even not at the level of the largest airport with 90 million PAX. They also found a strong indication of economies of scope between domestic and international passengers as well as between aviation and commercial non-aviation activities.

#### *4.3 Measuring Economies of Scope*

In Sec. 4.1 and 4.2 several studies dedicated to the measurement of economies of scale in the operation of an airport are shown. All of these studies leave out the fact that the airport business consists of several different operational activities and thus economies of scope can play a crucial role for the airport cost structure. The topic of economies of scope is rarely examined for the airport industry nevertheless some studies exist.

Tovar and Martin-Cejas (2009) analyzed the impact of outsourcing and diversified non-aeronautical activities on the efficiency airports. Their data sample consisted of 26 Spanish

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<sup>12</sup>MTOW = Maximum take off weight



airports from 1993-1996. They indicated three different outputs of the airports operation, ATM, the relation between passenger volume and ATM and the percentage of non-aeronautical revenue of the total revenues of the airports activities. As inputs they chose the average number of employees, the surface area of the airport, and the number of gates. They applied a translog distance function and measured the influence of outsourcing by defining it "as the share of soft cost inputs in total cost (Tovar and Martin-Cejas, 2009, p.218)".

As a result of their estimations they found that outsourcing of certain activities as well as a higher volume of commercial activities revenue has a positive effect on the technical efficiency of the airports. This leads to the conclusion that there are economies of scope between the aeronautical and the non-aeronautical business of the airport. Further investigation should be made to identify the activities which have a positive effect on the airports efficiency and the ones which should be outsourced.

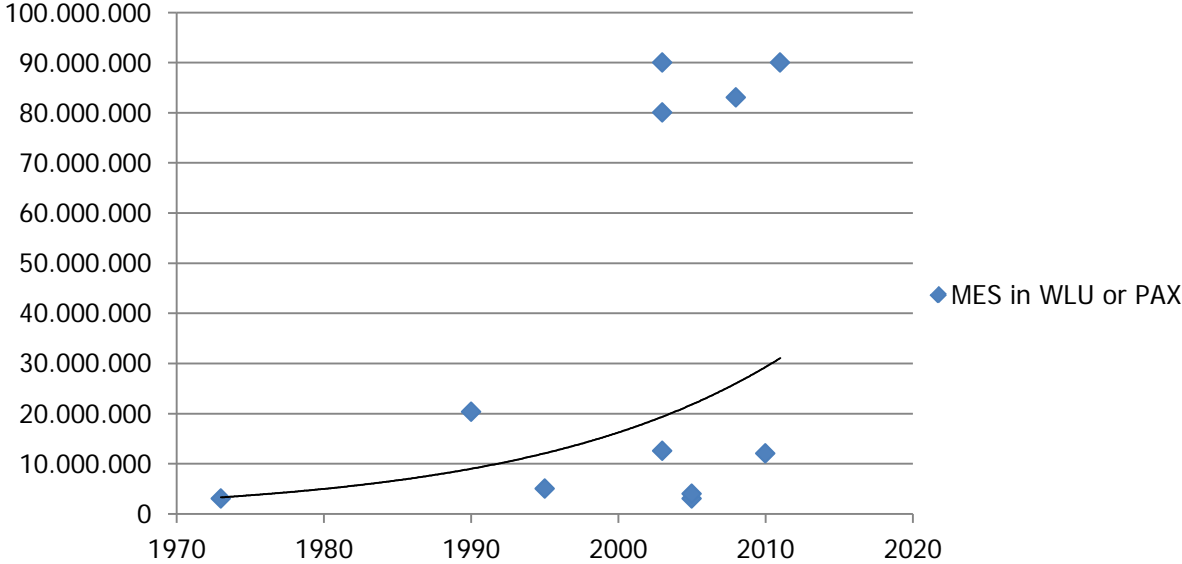
Chow and Fung (2009) analyzed the Chinese airport industry and investigated the possibility of economies of scope between air passenger movement (APM) and air cargo movement (ACM). Their dataset included 46 Chinese airports with data from 2000. In accordance with Pels et al. (2003) they used ATM as an input factor for the two outputs APM and ACM. ATM consisted of the inputs airport's surface area, the length of the runways and number of parking positions for the aircrafts. As ATM served as input for both APM and ACM Chow and Fung (op.cit.) added the passenger terminal area and the car-park area as further inputs for APM and the cargo handling area for ACM. Other variables included in their estimations were regional effects and the fact if the airport serves as an operational base for a major airline. They compared the results of a single output stochastic production frontier for each output with a multi-output stochastic production frontier. In doing so they reached the conclusion that economies of scope exist and that these economies have a significant effect on the estimation of the airports technical efficiency.

## **5. CRITICAL DISCUSSION**

The studies reach the conclusion that economies of scale exist, although the level at which these economies of scale are exhausted differs largely. While the early studies suggested that economics of scale run out at a level of 3 to 5 Million passengers later studies did not

confirm. Jeong seems to be the exception (see. table. 2). In Figure 2 the points of minimum efficient scales<sup>13</sup> (MES) of the surveyed studies are plotted along a time scale.

**Figure 2 - MES in WLU or PAX**



Source: Own research

We would argue that the MES has shifted over time because the output has increased over time. The early studies of Doganis and others did not contain none or at least not many airports of the size of 50 or 80 million passengers. Furthermore the number of observations of airports with 5 and more million passengers has increased making these estimates more reliable. Another important factor is that the increased aircraft size and load factors systematically shift the MES. The average passenger load at the three airports (see Figure 2) which were studied in the early studies have tripled turning a 3 million threshold into a 9 million<sup>14</sup>.

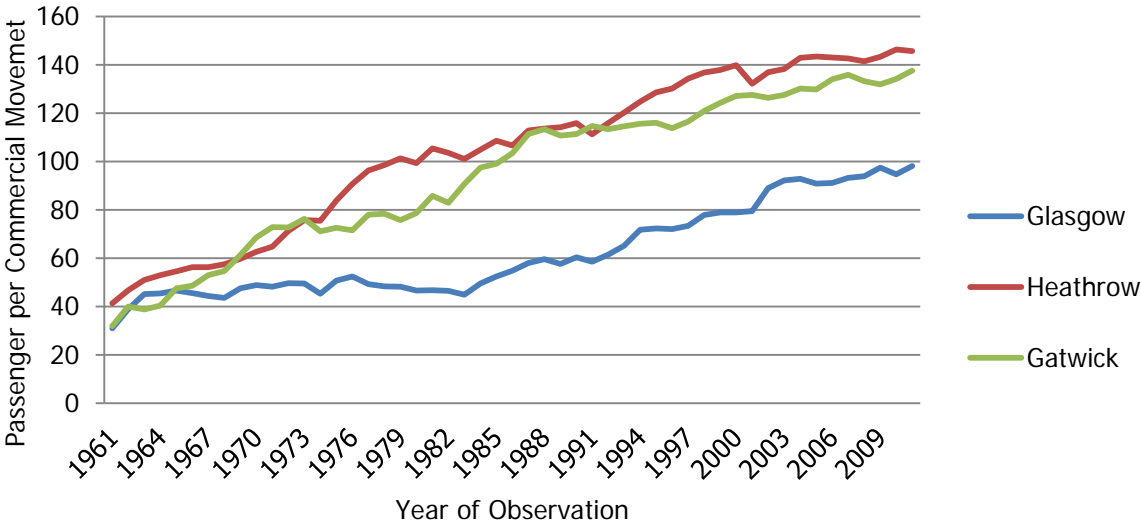
The increased airport size in the sample reflect that rising demand for the airport services leads to increases in economies of density and economies of scope. Early studies most probably have a larger share of airports with unrealized economies of scope and density.

<sup>13</sup> MES is the level at which economies of scale are exhausted. The results on MES are plotted irrespective of whether output is defined in WLU or passengers. This inaccuracy is acceptable as the values are rough estimations.

<sup>14</sup>We owe this hint to Mike Tretheway. Of course, this effect is not so strong at airports which have experienced less growth.

These airports have moved down the short run average cost curve and have lead to more observations with lower average costs. The estimations reflect this and lead to a higher MES. Another drawback of the studies is the definition of output. As shown in the analysis the most common output measure used is the so called WLU. This measure is introduced to incorporate the combination of passenger and cargo output. This is arbitrary since the production processes and machineries necessary for the handling of each differ substantially. So while useful for the output measurement of airline this output-factor is highly problematic measuring the output of airports (Doganis, 1992).

**Figure 3 - Development of Average Passenger Load**



Source: Own research

Defining output as WLU also means that the output of commercial activities is neglected. By focusing on only one fraction of the airport business the authors of these studies leave out the influence of the diversification of the airport business. Chow and Fung (2009) have proven that the existence of economies of scope have a strong influence on the measurement of the airports efficiency, indicating that the results of the studies concerned with only one aspect of the airport business give a false picture.

A further critical point in the studies can be found when airports of different countries are compared. International studies often failed to account for different accounting practices, which allow some costs to be excluded from the balance sheets. This makes a comparison between these airports very difficult as accounting costs and arbitrary accounting rules do not reflect economic costs.

The DEA methods draw their conclusion concerning economies of scale from the measurement of scale efficiency. Thus, not directly measuring the cost structure gives a clear indication to the existence of economies of scale in the operation of an airport. But nevertheless they do have some drawbacks which can easily lead to misinterpretations<sup>15</sup>.

Most studies of econometric estimations of the cost curve of the airport lag on the drawbacks of the Cobb-Douglas cost function. The estimations could increase their value if a translog cost function would have been applied as Tolofari et al. (1990) did. However he has chosen a sample size too small to draw generalized conclusions concerning the airport industry. Jeong (2005) who also chose a translog form of the cost function leaned his estimation on Tolofari et al. (op.cit.). Jeong admits that his picture is incomplete because he only focuses on output economies of scale but that this is due to a lack of data and information. Doganis et al. (1995) separated the airport's activities and only looked at the core competence to compare the different airports. This is the major drawback of all studies. They all leave out the fact that the airport business is much diversified and does not consist of airside activity only. By separating the different activities of airports the described studies leave out possible influences of other airports activities or entities on the performance of the analyzed airports.

The studies show no diseconomies of scale which is surprising given the complexities of large airports, scarcity of land at large airports in metropolitan areas and signs of bureaucratic management. In this respect it is important that the costs measured in these studies are only the private costs of airports which do not reflect costs for the users in form of longer taxi times for aircrafts or longer path for passenger to reach the gate. Other external cost caused by noise and emission are excluded as well as external benefits.

## **6. CONCLUSION**

Our survey shows that the standard view that economies of scale run out at a level of three or five million passengers is not supported anymore by more recent research, especially the more sophisticated studies of Martin and Voltes-Dorta (2008 and 2011) confirm the view that in many local markets airports are strong or at least weak natural monopolies. These barriers

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<sup>15</sup>Pels et al. (2003) leave out the labor inputs of airport operation although according to Doganis (1992) they make up a high proportion of overall inputs cost. Vogel (2005) gives only very limited information about his calculation.

to entry need to be further studied in analyzing airport competition and regulation (Forsyth et al. 2010).

Just a few studies try to analyze the economies of scope. They clearly show that economies of scope exist and that they play an important role in the measurement of the airports efficiency. If not included in the estimation, the results of the estimations will be incomplete and thus might lead to wrong conclusions.

In a nutshell, the literature on economies of scale and scope seems currently to suggest that airports are at least weak natural monopolies, but given the renewed interest in airport competition and regulation further studies need to be conducted capturing the multi-product nature of the capital intensive airport industry.

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# AIRPORT SECURITY: CURRENT PRACTICE AND PERSPECTIVES FOR 2030

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## ABSTRACT

The high profile of aviation has made it an attractive target to terrorist activities. The September 11 terrorist attack and subsequent failed terrorist attacks made safety and security top priorities for the aviation industry. A review of the current practice in airport security conducted by the author found that it was reactive, expensive and inefficient in some areas based on a "one-size-fits-all" principle. The forecast of a new approach to airport security conducted in this study predicted that by 2020-2030 airport security will be proactive and based on passenger differentiation.

Keywords: Airport security, risk-based approach, scenario-based approach, passenger, differentiation, proactive.

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## 1. INTRODUCTION

Since September 11, 2001, airport security has taken new dimensions throughout the world. Airport security has become a regular part of the passenger travel experience as a lot of attention is being paid to different ways the processes and procedures can be made more efficient and effective. In spite of improved measures introduced for airport screening and for the accurate identification of people whether they happen to be airport staff, passengers or contractors on airport sites, there have been several attempted terrorist attacks on commercial flights since September 11.

In December 2001, Richard Reid on board an American Airlines flight from Paris to Miami attempted to ignite an explosive device hidden in his shoe. Also in 2008, a Somali woman attempted to hijack an Air New Zealand flight and most recently a Nigerian national named Umar Farouk Abdulmutallab on December 25 2009 attempted to detonate an explosive device in his trousers while on board a Delta flight from Amsterdam to Detroit (Holbrook, 2010). How did all these dangerous individuals come so close to achieving their terrorist objectives when airport security was greatly improved after September 11, 2001 (Holbrook, 2010)?

In addition to those setbacks, the operation of the present airport security system has put the burden of space, layout, training of staff, technology and inflexibility of processes on airport operators. Passengers have also been dealing with long security lines, complexity of rules and often invasive processes (IATA, 2013). The need to modernize and improve passenger security screening at airports has become a topic of discussion across the aviation industry. The paper will review the current practices in airport security; consider some new approaches that are emerging in the industry and attempt to forecast an approach to airport security for the 2020-2030 timeframe.

## 2. PURPOSE OF THE STUDY

There have been several developments in recent years related to more efficient airport security such as the implementation of machine readable passport, introduction of more sophisticated scanners at checkpoints and addition of new items on the list of items banned in bags permitted in the cabin. In spite of these developments, threats to aviation security still remain, thus the constant search for more efficiency in airport security. The intent of this research is to forecast the approach in 2030 taking into consideration current practices and emerging trends in airport security.

### 3. SCOPE OF THE STUDY

This study will not consider aviation security as a whole but will focus on aviation security at the airport level only. Airport security is an important component of aviation security. In considering airport security, the focus of this study will only cover passenger security at the airport, baggage and cargo screening.

### 4. IMPORTANCE OF THE STUDY

According to Napolitano, the former United States Secretary of Homeland Security, aviation security tops the priority list of the Department of Home Security (Peters, 2010). Safety and security continue to be on the priority list of the aviation industry. Moreover, the combination of the predicted growth in air travel and the continuously evolving security threats makes it important that the current approach to airport security be reviewed and we forecast a future approach to airport security that will secure the expected growth in air travel.

### 5. LITERATURE REVIEW

The introduction of biometrics at airport checkpoints was greeted with great hope. Houdeau (2009) considered biometric identification as a necessary check for travel documents, border control and immigration. Houdeau argued that three biometric technologies have emerged: (1) face recognition applied in areas such as e-passport, (2) fingerprint recognition applied for Schengen visa and (3) iris recognition.

One of the challenges facing airport managers is the ability to accurately identify people in the airport environment, whether they are passengers, staff or contractual workers who need to work on-site at the airport. Airport security needs a tool that will help determine who and then certify all who need to have access to critical airport areas. Elliot (2009) while analyzing the importance of biometrics for airport security argued that biometrics could be useful mostly to mitigate the limitations of personal identification number (PIN) access. He believed that the use of face recognition technology was a compelling solution offered by biometrics when compared to a PIN that could be lost or stolen. Elliot (2009) presented other biometrics such as finger-prints, iris and palm.

Moreover, reactions to the September 11, 2001 terrorist attacks renewed further attention to biometrics. However, Gold (2012) analyzed the performance of the biometrically-enabled e-gates which were expected to speed up immigration checks at London Heathrow Airport and found that they actually slowed the passengers down, even when the e-gates systems were

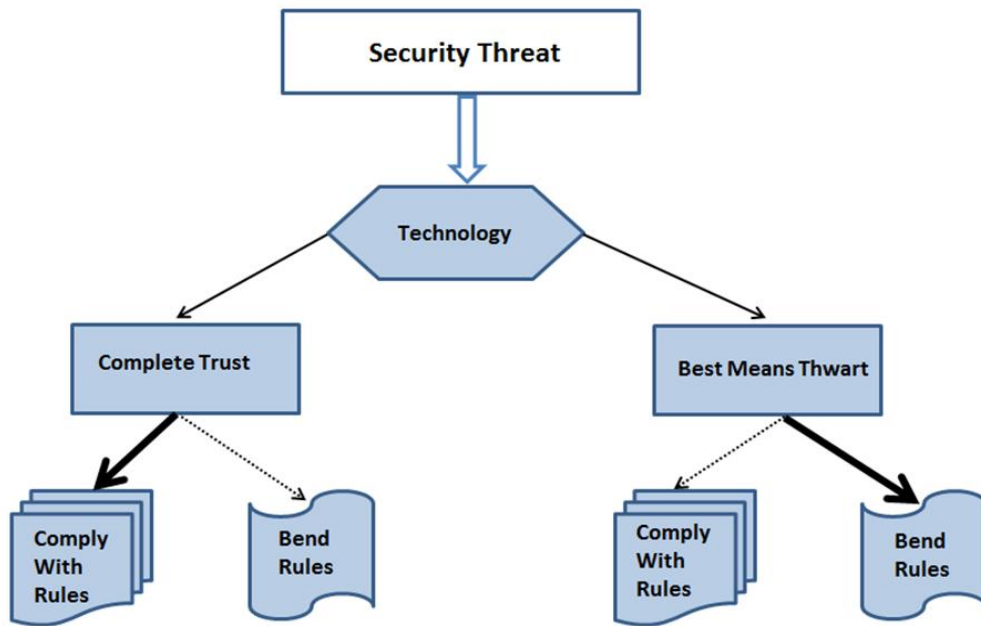
set to allow false positive. It was found that the facial recognition system at the e-gates lost its sensitivity to the point that a woman could pass through the gate using her husband's passport by accident (Gold, 2012).

The challenges presently encountered in airport security are not limited to biometrics. IATA (2013) in its review of the present state of airport security found that there was no connectivity and networking within the airport checkpoints and with other systems at airports. This has been resulting in airports systems acting independently. The situation has also reduced their ability to provide real time data that can enhance passenger screening at airport checkpoints. At many airports, there is neither communication nor coordination between the immigration checkpoints and the passenger and cabin baggage checkpoints.

Kirschenbaum, Mariani, Gulijk, Rapaport & Lubasz (2012) considered the issue of the technological adequacy at airport checkpoints from the human and technology perspectives. They conducted a field survey of airport employees spread over eight airports in Europe to analyze the relationship between the trust in security technology and the implementation of security rules and regulations at airports. To guide their research Kirschenbaum et al (2012) posited a theoretical working model (Figure 1 below) that considered trusting technology as a two-pronged construct consisting in complete trust in security technology devise and a means of obtaining a security decision. The employee's trust in either of the two views could have an impact on the level of compliance with security rules and protocol.

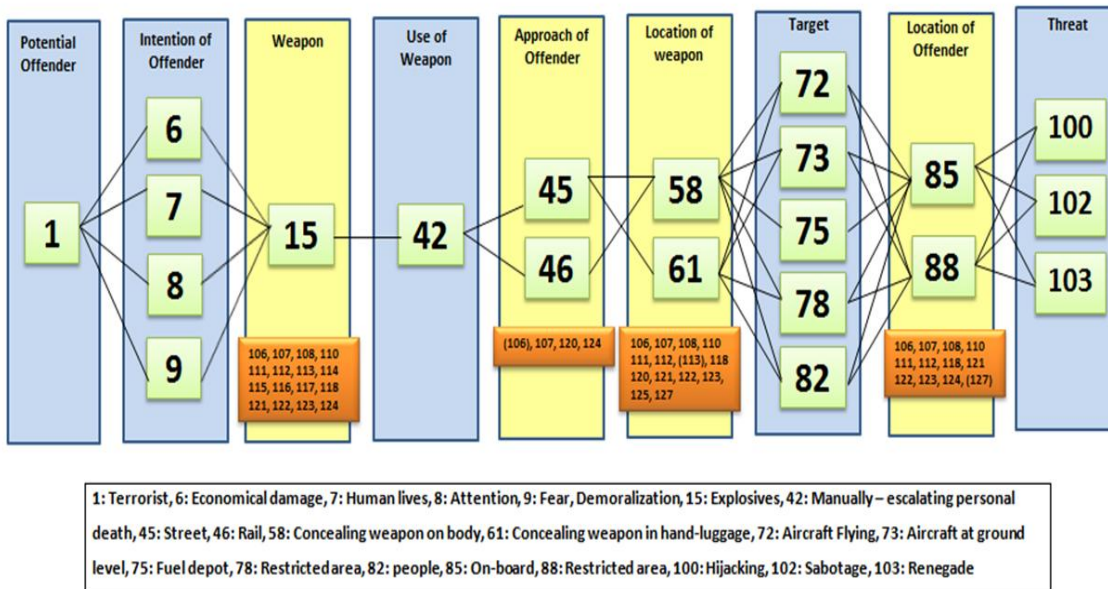
The study found that employees who completely trusted security technology tended to follow the rules. Those who consider security technology as a best means of catching offenders tended to bend or break the rules if the situation called for it (Kirschenbaum et al, 2012). The above technological setbacks and the human factor challenges in aviation security are driving research for a new approach to airport security. Cole & Kuhlmann (2012) advocated for a scenario-based approach to airport security. Having observed that so far aviation security has been reactionary to threats, they researched the application of enhanced scenario-planning methods to airport security to make it proactive. Their approach has the merit of determining threat scenario clusters. The analysis of those scenarios could help airport security operatives: (1) better anticipate possible future threats, (2) identify weak points in the security architecture for improvement and (3) put in place effective security measures to counter threats before they manifest. Through figure 2 below, Cole & Kuhlmann (2012) illustrated how some threat scenarios can be opposed to security counter-actions and be exposed.

Figure 1 - Theoretical working model of security decision making tree linking technology and compliance to security rules



Source: Kirschenbaum et al (2012)

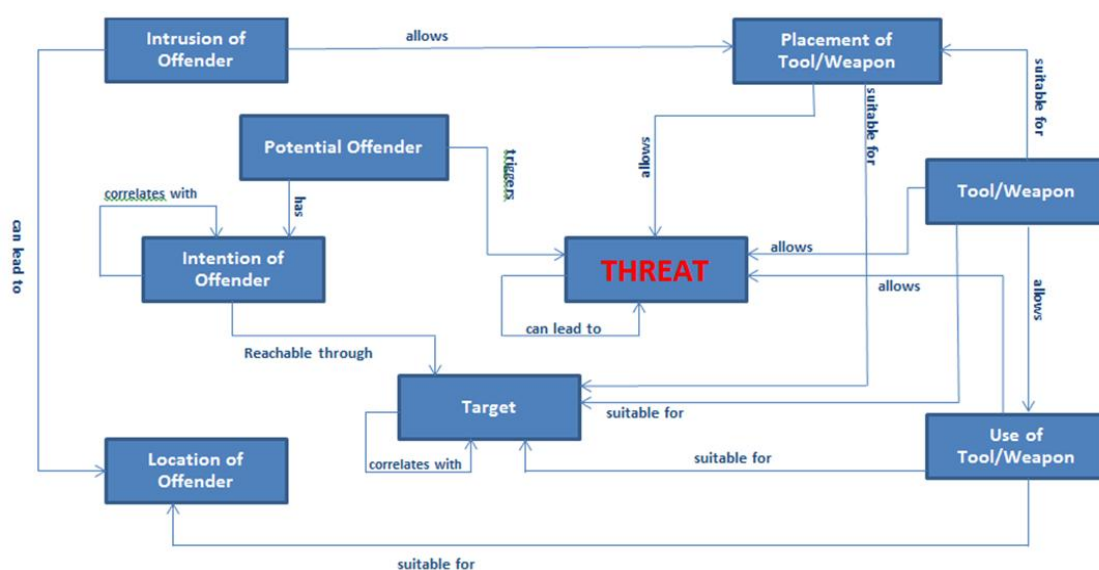
Figure 2 - Threat Scenario Cluster with respective Security Measures



Source: Cole & Kuhlmann (2012)

In the flow chart of figure 3 below, the authors looked at some domains that constituted scenarios and how they were interlinked. The arrows in the flow chart represent not only the direction but also the quality of the relation between two domains. Threat scenarios are built from the relations between the domains. The work of Cole & Kuhlmann (2012) is channeling a course for airport security in the future. It is a departure from the present reactionary and “one-size-fits-all” approach that relied mostly on technological improvement and moving to a scenario-based proactive approach.

Figure 3 - Details of flowchart (showing 9 out of 15 domains)



Source: Cole & Kuhlmann (2012)

## 6. RESEARCH DESIGN

Further to the literature review (important for this research), the author reviewed past and present approaches to airport security in order to determine their strengths and weaknesses. The research then proceeded with a forecast for airport security in the 2030 time frame. As the subject involves a review of past and current practices in airport security, the researcher made use of documents and other archival materials. The author used the archival design to achieve his research objectives. Vogt, Gardner & Haefele (2012) recommended the use of an archival design when the subject involves the past or when the materials are not currently available. Articles from peer-reviewed journals were the primary source of literature for this study. While not extensive, the researcher found some articles related to airport security that have been published by peer-reviewed journals. Also, important policy

documents for the aviation industry such as Annex 17 of ICAO that relates to aviation security were also consulted extensively.

## 7. ANALYSIS

### *7.1 Current Practices in Airport Security*

#### A) National Standards

Annex 17 of ICAO provides some broad standards and recommended practices (SARPs) for the handling of aviation security. Those recommended practices have been adopted by many countries and integrated in their national standards. Even though some commonalities can be observed in the operation of airport security, the practice of airport security is based on national standards and regulations. Therefore, the practice of airport security is not uniform worldwide. This explains why a passenger may be required to observe a security measure in one country and not be required to observe the same measure in another.

In the European Union (EU), the Commission Regulation (EU) 185/2010 set forth the measures for the implementation of the common basic standards for aviation security. In the United Kingdom (UK), the Department for Transport (DFT) is responsible for airport security. The UK has been contemplating the use of new methods of passenger screening for more efficiency. In India, due to the location of slums close to some airports, passengers can be required to undergo additional searching of hand luggage. In Israel, passengers leaving the country are checked against a computerized list maintained by the Israeli Ministry of Interior (Wikipedia, 2013). Airport security standards are not globally harmonised.

#### B) Operations of Airport Security

The current practice in passenger screening at airports has consisted of making all departing passengers go through a minimum of two checkpoints. The first checkpoint is the border control where often biometrics are used to authenticate travel documents which ensures that the bearer of the travel document is the person described in the travel document and ascertains that the passenger has the required documentation to cross over the border. Biometrics technology such as iris recognition, fingerprint recognition and face recognition are used by border control agents to achieve their purpose of identification, verification and authentication. Some countries support the biometrics with security intelligence information stored in border control systems. Biometrics have helped to curb the use of impersonation and fake documentation. The matching of the finger prints on the travel document is now



compared with those collected from the traveler at immigration checkpoints when entering the country to help reveal impersonation.

However, as highlighted in the literature review, biometric technology has shown its limitations for example the failure of face recognition technology which allowed a woman traveling with her husband passport to pass through an e-gate in London (Gold, 2012). Building redundancies and constant improvement in biometric technology, supported with strong passenger intelligence data, will help to improve the efficiency of border control checkpoint. The efficiency of border control checkpoints also hinges on reducing long queues at immigration checkpoints.

Passenger and cabin baggage screening point is another checkpoint that all passengers are required to go through before proceeding to board their flights. Typically, at this checkpoint, all passengers are requested to walk through a metal detector or a body scanner machine. Passengers who trigger the alarm of the metal detector machine or body scanner are taken through a secondary check that may involve a pat down. At times passengers are also randomly selected for a secondary screening. In some less developed countries where airport security infrastructure is adjudged minimal or average, airlines take it upon themselves to conduct a secondary passenger and cabin baggage screening before boarding in order to protect their flights. This practice of secondary screening has been a source of additional cost for airlines and an additional hurdle for passengers.

While the passenger is walking through the metal detector, cabin baggage is taken through a separate x-rate device. According to national standards, the cabin baggage control may require screening of coats, jackets, belts, shoes, laptops, gels, liquids and aerosols. At prominent airports and at times randomly, explosive trace detection devices are used to screen cabin baggage.

After the Lockerbie bombing, screening of check-in baggage that is loaded into the hold of aircraft was introduced in the standards and recommended practices of Annex 17 of ICAO. The Annex 17 recommends 100% screening of hold baggage for the detection of explosives. The practice of loading only the baggage of passengers who have boarded the aircraft became a standard for the dispatch of commercial flights. Airlines have been practicing passenger and baggage reconciliation. This practice explains the fact that flights do not depart until the loaded baggage of a passenger who misses his/her flight is off-loaded.

From the above we can observe that the current operation of airport security is characterized by long queues and redundancies. A passenger with many connections can be screened three or four times on any particular journey if they leave the airports secure area. The passenger may be screened at every airport where he/she makes a connection. Also there is lack of connectivity between the checkpoints. For example, at many airports, there is no live exchange of information between the airline check-in desk, the immigration checkpoint, and the airport security checkpoint.

#### C) Present Reactionary Approach to Airport Security

The present approach to airport security has been highly reactive. It lacks in proactive qualities. The screening of passenger shoes at checkpoints was not introduced until a passenger concealed explosive device in his shoes. Similarly, the screening of liquid was not instituted until a passenger attempted to use some liquid substances for explosive purposes. The scenario applies to the Christmas Day bomber who was able to pass through many security checkpoints through many countries without the explosive concealed in his trousers being detected. Full body scanning was not introduced until after the failed attempt. Thus, the threats have been ahead of security measures. Therefore one can argue that the present airport security approach has only been reacting after damage has been done or after a failed attempt or a near miss. Airport security must move from a reactive approach to one that is proactive.

#### D) Airport Security Funding

Airport security in its present form is expensive. It was reported that the American TSA employed about 50,000-person workforce in 2010, those employees screened an average of 2 million travelers a day across 457 airports (Ott, 2010). This puts a heavy financial burden not only on the state but also on the airlines and passengers. Airlines spend approximately \$8.55 billion per year on security related costs (IATA, 2013).

In countries where airlines have to provide secondary screening to secure their assets, they bear the burden of additional cost in a business that is marginally profitable. Some governments introduced security taxes and charges to fund airport security expenses. Those security taxes are collected through additional passenger charges on the flight tickets. These charges lead to an increased airfare which, in turn, negatively impact demand for air travel (Vasigh, Fleming & Tacker, 2008). The aviation industry needs to find an efficient and cost-

effective approach to airport security that will mitigate the negative impact of airport security charges on the demand for air travel.

### *7.2 Trends and Future Perspectives for Airport Security*

From the above review, one can arguably state that the present airport security is reactionary, expensive, based on a uniform approach and lacks efficiency in some areas. The new approach to airport security attempts to mitigate those setbacks. If a new approach to airport security is to find acceptance in the aviation industry, it has to be proactive, more efficient and less expensive than the current approach.

#### A) Scenario-Based Airport Security

The scenario-based approach to airport security proposed by Cole & Kuhlmann (2012) is certainly a step in the right direction and departs from the reactionary approach. Using a scenario-based approach, airport security managers will be able to generate clusters of possible scenarios of threats to airport security that will give them the opportunity to proactively devise measures to counter those threats before they are carried out. Threat scenarios will also help airport security managers review the existing airport security architecture and thus help to detect areas of weakness. Moreover, the scenario-based approach departs from the uniform approach that applies the same level of screening to all passengers. With the scenario-based approach, airport security rules will not apply to all passengers the same way and will depend on the outcome of played out scenarios. This fulfills some expectations of the new approach to airport security as stated above.

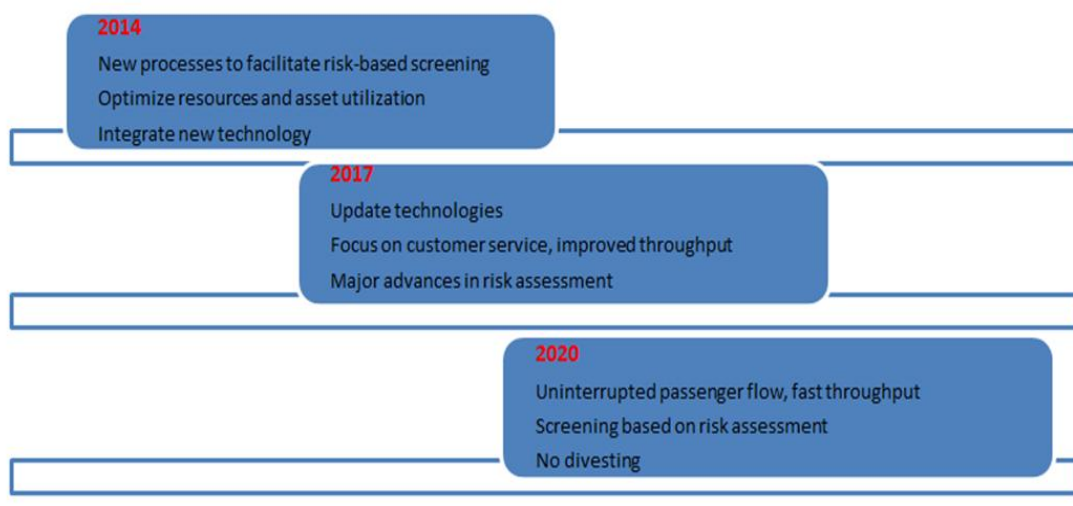
However, the challenge of this approach is the lack of certainty that all possible scenarios have been captured by the system at any given time. The reliance on literature and airport security experts for the generation of domains that will form into scenarios may not be sustainable. As in aviation safety, a scenario-based approach will need a voluntary reporting system that will be a reservoir of domains that can be used to make complete scenarios.

#### B) The IATA Checkpoint of the Future: A Risk-Based Approach

The International Air Transport Association (IATA) having found that the current approach to airport security is not sustainable due to the projected future growth in air travel, has been advocating for a "Checkpoint of the future" that is a risk-based approach focused on: (1) strengthening security, (2) increasing operational efficiency and (3) improving the passenger experience (IATA, 2013).

IATA believes that threats to aviation security are generated by a very few number of travelers. The great majority of passengers are of no threat to aviation security. It is therefore not necessary to subject all the passengers to the same level of screening at airport checkpoints. Thus, its advocacy for a risk-based passenger differentiation whereby air travelers are screened differently according to their levels of risk (IATA, 2013). The risk assessment process cannot be based on religion, race or gender but it will be based on travel data, intelligence gathering, voluntarily contributed information and behavior detection technique. It will be a continuous process that spans from reservation to boarding (IATA, 2013). IATA proposed a phased approach which will result in uninterrupted passenger flow and fast throughput by 2020 as shown in figure 4 below.

Figure 4 - IATA phased approach risk-based aviation security



Source: IATA (2013)

### 7.3 Complementarity of the Scenario-Based Approach and the Risk-Based Approach

IATA's "Check Point of the Future" is a risk-based approach geared toward passenger facilitation at airports with one of its major outcomes being passenger differentiation which consists of screening passengers based on their category's profile, thereby leading to improved efficiency and security at airports. The risk assessment component of IATA's "Check Point of the Future" requires a more robust approach than the current approach based on passenger data, behavior analysis and identity management to gain the trust of national regulatory authorities. It needs to be based on a proactive process that is able to identify not only historic threats but also future threats. This anticipatory process is provided by the scenario-based approach of Cole & Kuhlmann (2012).

Risk is defined by the following equation where R stands for risk, S for severity and L for likelihood: Risk equals severity x likelihood (Stolzer, Halford & Goglia, 2008).

$$R = S \times L \quad (1)$$

The likelihood element in the risk assessment of the "Check Point of the Future" is provided by the scenario-based approach of Cole & Kuhlmann (2012) which follows the process of; (a) environmental scanning, (b) selection of threat elements, (c) reduction of connections, (d) cross-impact analysis and (e) scenario building.

On the other hand, a scenario-based approach to airport security is incomplete if it does not ultimately lead to improved passenger facilitation at airport checkpoints as advocated by IATA's "Check Point of the Future". Therefore, it is recommended that the airport security perspective for 2030 should include an integration of the scenario-based approach of Cole & Kuhlmann (2012) and the risk-based approach of IATA's "Check Point of the Future".

## 8. CONCLUSION

In summary, it is abundantly clear that the present rigid and predictable "one-size-fits-all" approach to airport security is not a desirable situation for screening today; neither will it be for the next generation of airport security (IATA, 2013). The industry needs to move from today's approach to airport security screening to a new approach that focuses on security outcome, process improvement and technology. One can forecast that the approach to airport security by 2030 will be different from the current approach.

The IATA concept of the "Checkpoint of the Future" and the Cole & Kuhlmann (2012) concept of scenario-based approach to airport security are not mutually exclusive of each other. They both advocate for a departure from the present approach of uniform airport security screening applied the same way to all passengers irrespective of their levels of risk. The new approach to airport security will not be "one-size-fits-all" but it will be based on passenger differentiation, supported by a scenario-based approach. Airport security approaches recently adopted by key global aviation stakeholders support IATA and Cole & Kuhlmann perspectives. Recently, the American Transportation Security Administration (TSA) acknowledged a move toward pre-screening in order to separate passengers and baggage that do not require extra layers of screening (Grimaldi, 2012). Also, ICAO and the Global Air

Cargo Advisory Group (GACAG) have agreed to support a risk-based approach to be adopted by airlines and cargo forwarders for security screening at airports (Grimaldi, 2012).

Given the success of the proactive approach in aviation safety through the implementation of safety management system (SMS), it can be predicted that a similar proactive approach may be considered before 2030 for airport security within the global aviation security community. There will be a push for the adoption of a Security Management System (SeMS) that will help regulators, governments and other aviation stakeholders measure the effectiveness of airport security policies and also create a security culture in organizations such as airports and airlines.

One can also forecast a future approach to airport security where various individual government standards and regulations related to airport security are harmonized into globally accepted standards that eliminates redundancies and duplications that are currently observed. Passengers and airlines will benefit greatly from the global airport security standards based on internationally agreed upon standards (IATA, 2013).

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# EVALUATION AND SELECTION OF A FLEET OF AIRCRAFT LOCATED IN MADNIAH, SAUDI ARABIA

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## ABSTRACT

The present work simulates the evaluation and selection of a fleet of aircraft for a proposed airline located in Madniah, Saudi Arabia, to operate across an assumed network that includes both local and international destinations. This simulation is conducted through a series of phases and subsequent deeper and meticulous levels of analysis. At the end of these phases some recommendations are given for selecting the suitable fleet. The phases are simulated using MS Excel and the output of the study predicts both the aircraft efficiency and its contribution to the net profit of the airline. Considering the destination ranges covered within the network and such other important criteria as the respective payloads, a number of candidate aircraft were chosen for the study. Finally, it was found from the study that 5 of the EMB170 aircraft would be the best choice for the proposed airline.

Keywords: Fleet Planning, Operating Cost, Fleet Selection

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## 1. INTRODUCTION

Aircraft fleet planning is perhaps the starting point for a new airline proposed to serve a given flight network in a prescribed region of the world. This paper addresses this precise need for a proposed start-up airline based in Madinah, Saudi Arabia to serve both national and international flight destinations. It is proposed that in its initial evolutionary stages, the airline will target Umra and Hajj travelers. The airline will offer an economy class service at affordable prices to all its customers. The airline will pointedly operate where there are strong potential links, the airline has a mission vision and objective.

Between the proposed city pairs within and outside of Saudi Arabia it is strongly anticipated that the level and the type of service offered together with the affordability will promote a growth in traffic generation between the city pairs.

### Mission:

- To provide a safe, reliable and value added air travel service in Saudi Arabia.

### Vision:

- The airline will be established as one of the leading regional and domestic airline, offering an economy service to passengers.
- The airline will create an environment in which the competent staff will be highly motivated and will drive customer satisfaction
- The airline will create an environment in which dedicated employees and effective management team will make every effort to improve efficiency and productivity whilst minimizing cost.
- The airline will achieve a steady growth
- The airline will fill a very important gap in the airline industry where the increased demand for Umra and Hajj is necessarily picked up by adjustment to operating schedules of other carriers.

### Objective:

- To consistently deliver a high level punctuality
- To offer a reliable and convenient schedule of air service in the region

- To generate a high level of demand for the airline
- To offer customers a competitive product at an affordable price
- To generate a satisfactory rate of return.

#### General Airline Operational Procedures

Most airlines operate under a well designed, well organized and established structure. Understanding the airline operation and structure is an important step for better understanding of the airline world. Airlines have generally evolved sound and very technical procedures in handling different aircraft designs. They operate under tried and tested strategies, on when to buy, sell, or rent an aircraft. Important information is available a priori on aircraft performance details and parent aircraft industry to investigate the suitability of a given aircraft for a given airline. Other such information as the capacity and number of hangars and their individual dimensions would be required for accommodating types and number of aircraft. If there is an industrial urgency to outsource some of their maintenance services other tasks and services, or even a number of employees and their salaries, the airline must plan for that. It is a well known fact that a given aircraft would be suitable for a large carrier but not suitable for a small carrier.

For a proposed burgeoning airline, the base maintenance would include all major checks that need to be carried out in a hanger usually in the base. Other line maintenance tasks are conducted every flight or day for the aircraft. Ground time or turn round time is an important issue to the airline industry. It is where aircraft, airline, airport, and air traffic control clearly interact. Ground time is important for the airline industry because the lower the ground time the higher the utilization of the aircraft and this would lower the direct operating costs. Ground time is also important for the airports. Lower ground time reduces congestion at the airport. The airports would then handle more travellers.

To make a successful plan, a fleet planner must incorporate ground time, flight times and other maintenance times into consideration quite early in the planning stage. Therefore, ground time is necessarily accounted for while building the airline fleet plan model. In real life each aircraft has its ground time, which depends on a number of elements such as range of flight, whether the flight is domestic or international, is the aircraft at the base or not, the capacity of the flight, the design of the aircraft, and other factors.

## 2. FLEET PLANNING

Fleet planning is very important for any airline. Fleet planning determines what type and what number of aircraft the airline should buy, in order to achieve the airline goals. Fleet planners also get involved in the negotiation deals with aircraft and engine manufactures. Most decisions are arrived at after due considerations of the pertinent flight missions. So by understanding basic elements of fleet planning, one would essentially understand the airline needs and operation parameters.

It should be noted that there are other factors that influence the new aircraft purchase that do not depend on fleet planning. These would include such deliberations as alliance with other operators, people factors and communality (Clark, 2001).

For example The Airbus, when marketing their Aircraft emphasize upon communality amongst their aircraft and point to the advantage of having a fleet of different type and size of aircraft from Airbus inventory. These advantages address such issues as:

- Expediency of time needed in training pilots on aircraft from their inventory.
- Efficiency in time in training maintenance manpower on aircraft from the same source industry.
- Since the systems are similar and properly use the same tools and procedures for maintenance or even operational such as refuelling, or baggage handing, that would have a big effect on the operational cost.

The only real disadvantage is that having similar aircraft from the same manufacturer would make negotiations for new purchases from a new vendor somewhat difficult as there would be little or no residential familiarity for other aircraft. A mixed inventory would provide better leverage in new transactions.

It is important to note that fleet planning is not just aircraft evaluation, aircraft comparison, route analysis, aircraft acquisition, or matching supply to demand in isolation but includes all these elements simultaneously (Clark, 2001).

A better understanding of fleet planning procedures and the evaluation of aircraft deployments in an airline would help construct the overall flight operational model. One of the most difficult decisions in an airline is whether to buy a new or a used aircraft. Decide upon what type of aircraft would be required for purchase or lease or go for renewing the existing aircraft.

The dilemmas of fleet planning of an airline is that

- Fleet Complexity
- Decisions must be long term
- Market volatility
- Heterogeneity of Networks

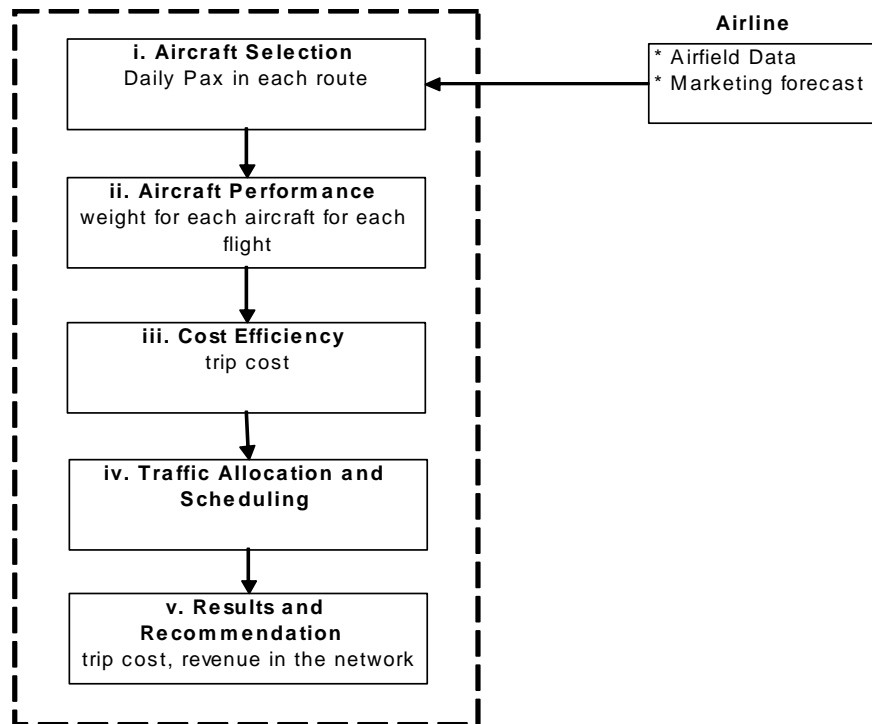
In fact the fleet planning is a compromise amongst a large number of competing imperatives. Each airline has a different approach towards the replacement of its aircraft. There are *large airlines which are government supported, small airlines, or capital rich airlines*, all would have a different aircraft average age, but they all follow the simpler principle of fleet planning.

Fleet planning is an on going process over the life cycle from the evaluation through disposal and data collection. More details are available in Clark (2001).

### 3. APPROACH

The emphasis will be on the interaction and competing interests amongst all of the above mentioned elements. Establishing a model which addresses the complexity of above issues in combination would help in the decision making of the fleet planning. Modelling remains an important step to gain an understanding of how the air transport world acts and interacts. It represents the most challenging task in constructing a unified strategy from a large number of disciplines that need to be covered and their mutual interaction in building up the functional flight model. Typically fleet planning evaluation and selection in the airline for a number of aircraft can be broken down into five main steps as shown in Figure 1 (Roskam, 1990a).

Figure 1 - Typical Practical Steps in Fleet Planning



Source: Roskam (1990a)

These steps are:

1. *The Process of Aircraft Selection.* The first set of input data for this step would be from the airline in the process of selecting an aircraft, the input data would be *airfield data* which includes (elevation, temperature, runway length and surfaces, etc). The selection is based on the operation of regional jets from Madinah to selected destinations in a network that includes local destinations such as Riyadh, and Dammam, and International destinations such as Beirut, Dubai, Cairo and Istanbul. Table 1, Shows the airfield data for the mentioned cities. Table 2 shows the aircraft that have been selected for the study, their engine type and the associated weights. The second source of information would be the *Market Forecast*, Table 3, which includes assumed data such as growth rates, frequency, saturation load, etc. The last set of information needed in this process is domestic, regional, and international network distances. After making an analysis, the output of this step would be the daily passenger profile for each sector in the long and short term and a payload range plot. The aircraft candidates would then be determined in this step.

Table 1 - Airfield Data

Airfield City (+IATA Code)	Eleva. ft	Temp C	Runway Length ft
Madinah (MED)	2151	23	12657
Jeddah (JED)	48	25	12491
Riyadh (RUH)	2049	22	13829
Dammam (DMM)	72	26	13165
Cairo (CAI)	382	21	13127
Istanbul (IST)	163	17	9813
Dubai (DXB)	34	26	13143

Source: Roskam (1990b)

Table 2 - Aircraft Type

Aircraft Type	Engine Type	OMM lb	MFW lb	MTOW lb	MPLW lb
EMB170	CF34-8E	46165	20887	79344	12292
B717-200	BR715-30	68500	29500	121000	23000
A318-200	CFM56-5	84600	42080	145500	18820

Note: All has an Aux. Power Unit  
 OMM: Operating Weight Empty  
 MFW: Max. Fuel Weight  
 MTOW: Max. Takeoff Weight

Source: Snow (2004)

Table 3 - Market Forecast

Sectors From To	Ann. Pax Each way	Growth p.a.	Frequency	Staturation Load %	Yield \$/nm
MED - JED	24000	5	2D	85	0.25
MED - RUH	16000	5	3D	85	0.25
MED - DMM	8000	10	D	85	0.25
MED - CAI	42000	10	D	85	0.25
MED - IST	28000	10	2D	85	0.25
MED - DXB	16000	10	3D	85	0.25

Ann. Pax: Number of passengers yearly each way  
 p.a: per annum  
 D: Daily flights

2. *Detailed Aircraft Performance.* In the previous step the candidate aircraft has been identified. Therefore, the performance of each aircraft can be known, the airfield and en-route capabilities of these aircraft will be examined. After setting up some ground rules such

as time for taxi-in, time for taxi-out, time for start-up, the reserve fuel, the assumed alternative airport etc all for domestic and international routes, the output would be a weight breakdown and passenger payload in the network for each nominee aircraft and that by using Roskam (1990a, 1990b). That would give an indication of how many passengers a given aircraft can take.

3. *Cost Efficiency.* This step will indicate the economic suitability for each aircraft on a typical stage length or cost per trip. In this step some assumptions must be made to progress the economic analysis. Example of these assumptions would be fuel cost, cost of maintenance, annual insurance rate, annual salaries paid, etc, as shown in Table 4. The specific fuel consumption was given as specified by the manufacturers. The dollar year was assumed to be 2013. The engine maintenance labour rate used is \$12 per man hours, and the fuel price is assumed to be \$ 2.9 per US Gallon. Direct Operating Cost or (DOC) calculations were based on methods mentioned in World Airport Code (2013). DOC is an area where it is very tricky to get a third party reliability data source and airlines are very reluctant to provide data on their cost per stage length.

Table 4 - Assumed Parameters

Parameter	Value
Annual salary paid for one pilot [\$/year]	100000
Annual salary paid for one co-pilot [\$/year]	80000
Cost of maintenance materials for airplane [\$/n.m]	404
Cost of maintenance materials for engine [\$/n.m]	217
Annual hull insurance rate [\$/\$/year]	0.015
Maintenance man-hours per flight hours [hrs/hr]	5.86
Number of flight hours/year	750
Fuel density FD [lbs/gallons]	8
Fuel price FP [\$/gallons]	2.9
L/D	15
Engine maintenance labor rate [\$/hr]	12

The output would be a cost per trip per aircraft on the given network.

$$\text{DOC} = \text{DOC}_{\text{fly}} + \text{DOC}_{\text{maint}} + \text{DOC}_{\text{depr}} + \text{DOC}_{\text{lnr}} + \text{DOC}_{\text{fin}} \quad (1)$$

Where:

DOC<sub>fly</sub> is the direct operating cost of flying in \$/n.m.

DOC<sub>maint</sub> is the direct operating cost of maintenance in \$/n.m.

DOCdepr is the direct operating cost of depreciation in \$/n.m.  
 DOClnr is the direct operating cost of landing fees, navigation fees and taxes in \$/n.m.  
 DOCfin is the direct operating cost of finance in \$/n.m.  
 n.m. nautical miles

The DOCfly is given by

$$\text{DOCfly} = \text{Ccrew} + \text{Cpol} + \text{Cins} \quad (2)$$

Where:

Ccrew is crew cost given by

$$\text{Ccrew} = \text{SUM} [ ( n_{cj} ) \{ ( 1 + K_j ) / V_{bl} \} ( \text{SAL}_j / \text{AH}_j ) + ( \text{TEF}_j / V_{bl} ) ] \quad (3)$$

$n_{cj}$  is the number of crew member of each type (i.e. captain, and co-pilot)

$V_{bl}$  is the airplane block speed in n.m/hr.

$\text{SAL}_j$  is the annual salary paid to crew members of each type

$\text{AH}_j$  is the number of flight hours per year of each type

$\text{TEF}_j$  is the travel expense factor

$K_j$  factor which accounts for items such as vacation pay, cost of training

Cpol is the fuel and oil cost per nautical mile given by

$$\text{Cpol} = 1.05 ( Wf / R ) ( FP / FD ) \quad (4)$$

Wf is the fuel weight in lb

R range in n.m

FP is the price of fuel in \$ / gallon

FD is the fuel density in lbs / gallon

Cins is the airframe insurance cost in \$/n.m given by

$$\text{Cins} = ( \text{fins} ) ( \text{AMP} ) / \{ ( \text{Uann} ) ( V_{bl} ) \} \quad (5)$$

fins is the annual hull insurance rate in \$/\$/year

AMP is the airplane market price

Uann is the annual hour utilization



The DOC<sub>maint</sub> is given by

$$\text{DOC}_{\text{maint}} = \text{Clab/ap} + \text{Clap/eng} + \text{Cmat/ap} + \text{Cmat/eng} + \text{Camb} \quad (6)$$

Where

Clab/ap is the labor cost of airframe and systems in \$/n.m

$$\text{Clab/ap} = 1.03 (\text{MHRa}) (R / V_{bl}) \quad (7)$$

MHRa is number of airframe and systems maintenance hours needed per block hours

Clap/eng is the labor cost of engines in \$/n.m

$$\text{Clap/eng} = 1.03 (1.3) N_e (\text{MHRe}) (R / V_{bl}) \quad (8)$$

N<sub>e</sub> number of engines

MHRe is the number of engines maintenance hours needed per block hours

Cmat/ap is the cost of maintenance materials for the airframe and systems \$/n.m

Cmat/eng is the cost of maintenance materials for the engines \$/n.m

Camb is the applied maintenance burden in \$/n.m.

The DOC<sub>depr</sub> is given by

$$\text{DOC}_{\text{depr}} = \text{Cdap} + \text{Cdeng} + \text{Cdav} + \text{Cdapsp} + \text{Cdengsp} \quad (9)$$

Where

Cdap is the cost of airplane depreciation without engines in \$/n.m

Cdeng is the cost of engine depreciation in \$/n.m

Cdav is the cost of depreciation of avionics systems in \$/n.m

Cdapsp is the cost of the depreciation of airplane spare part in \$/n.m

Cdengsp is the cost of the depreciation of engine spare part in \$/n.m

The DOC<sub>lnr</sub> is given by

$$\text{DOC}_{\text{lnr}} = \text{Clf} + \text{Cnf} + \text{Crf} \quad (10)$$

Where

Clf the direct operating cost due to landing fees in (\$/n.m) are calculated by

$$\text{Clf} = (\text{Caplf}) / \{ (V_{bl}) (t) \} \quad (11)$$

Where

Caplf is the landing fees per landing given by

$$\text{Caplf} = 0.002\text{Wto } \$/\text{lbs} \quad (12)$$

Wto is the airplane takeoff weight in lbs

Cnf the navigation fees in \$/n.m

$$\text{Cnf} = ( \text{Capnf} ) / \{ ( V_{bl} ) ( t ) \} \quad (13)$$

Where

Capnf is the navigation fees charged per airplane per flight

Crt is the direct cost of registry taxies in (\$/n.m) are calculated by

$$\text{Crt} = ( \text{frt} ) \text{DOC} \quad (14)$$

Where frt is a factor suggested from Ref[6]

$$\text{Frt} = 0.001 + ( 10^{-8} ) \text{Wto} \quad (15)$$

Where

Wto takeoff weight in lbs

The DOCfin is given by

$$\text{DOCfin} = 0.07 \text{DOC} \quad (16)$$

In order to calculate the cost per aircraft per trip and the cost per seat mile, it is calculated as follows

$$\text{Cost per aircraft per trip} = \text{DOC } [ \$/\text{n.m} ] \times \text{Distance } [ \text{n.m} ] \quad (17)$$

$$\text{Cost per seat mile} = \text{DOC } [ \$/\text{n.m} ] \div \text{Number of seats} \quad (18)$$

More details are available in Taylor (2005).

4. *Traffic Allocation and Scheduling.* This step will identify the quantity of each aircraft required and schedule the flights. This would require some information such as ground time for each aircraft, refuelling time and other information or rules supplied by the commercial management department, such as, daily frequencies for a given aircraft on each route, international flight linked to domestic flights, and other ground rules such as aircraft limited to operating between 06:00 and 23:00 or frequency for international routes should be either 3 times a week or once a day. The output of this step is a flight schedule.

5. *Results and Recommendation.* Which should identify the preferred fleet choice by comparing trip cost, revenue, operating cost, results or total, number of passengers, ... etc with time.

#### 4. ASSUMPTIONS

In order to get the cost information about the airline, some relevant economic and operational data were either assumed or collected with the help of Saudi Arabian Airline.

In creating the model, some ground rules are assumed:

1. All maintenance checks are performed at the base airport.
2. There is at all times, at least one aircraft at stand-by for emergency circumstances
3. Each aircraft should undertake an inspection after each flight.
4. General ground rules have been assumed for various time slots. This includes time slot passengers embark, refuelling, passengers disembark, repair, inspection ...etc.

#### 5. RESULTS

An Excel programme created by the author was used to generate data for each aircraft type, by running the programme for 1, and 5 years, generating DOC (Direct Operating Costs), net contribution to profit share for each sector, and total contribution to profit for the entire fleet after 5 years. This provides a assessment of the impact of each aircraft type. The output information can be used by a Project Manager, or a Fleet Planner, to decided upon which aircraft would provide the best benefits or best results during flight operations. These results would be automatically processed to the fleet planner.

The study also shows that for the given annual passenger traffic and the growth rate, the airline would need 5 aircraft from the EMB170, or 3 aircraft from the B717, or 3 from the A318 aircraft.

Figure 2 shows the efficiency of each aircraft for a given sector. Different aircraft types are not only compared with their trip cost but also with their seat mile costs. When assessing such results it should be understood that, lower the two parameters for the given aircraft the better, the aircraft is said to be for more efficient if both parameters are low.

Figure 2 - Aircraft Efficiency

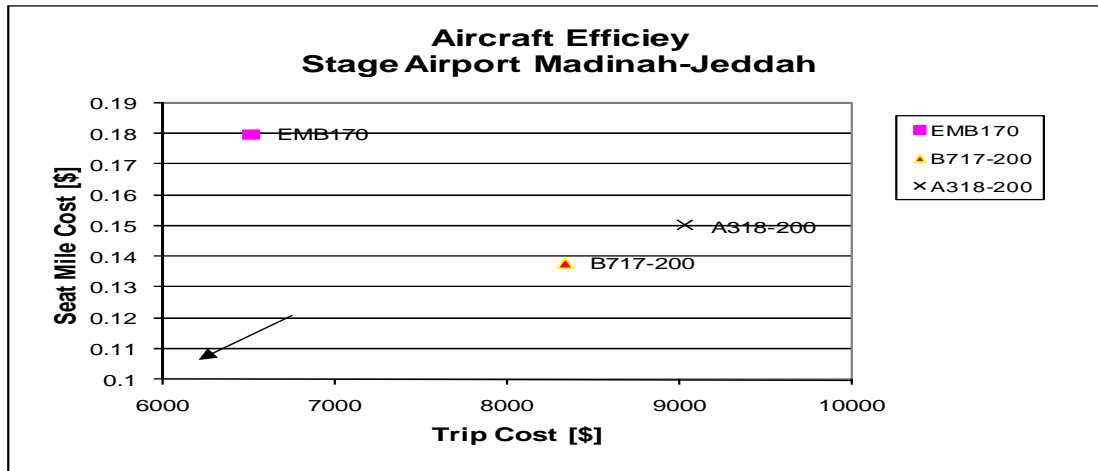
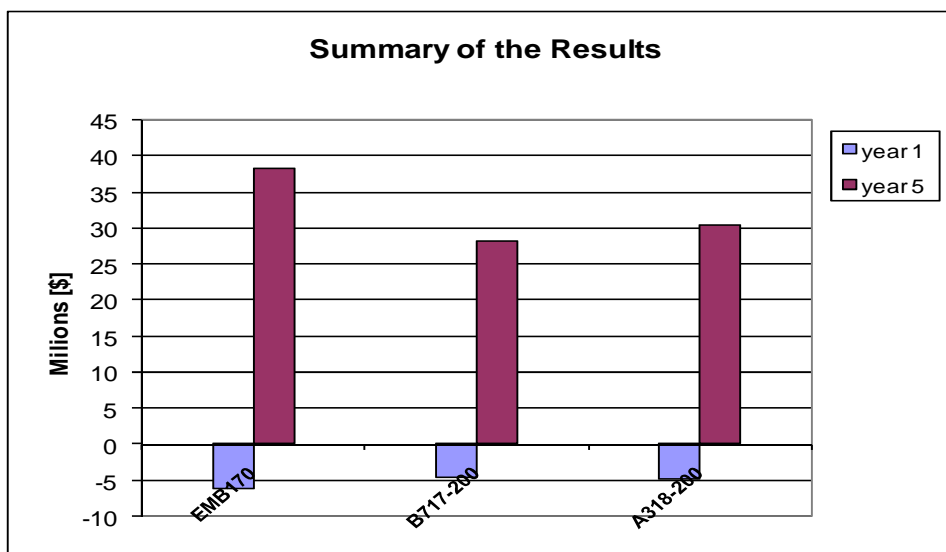


Figure 3 summarizes the study made for the 5 year time line for each aircraft operation under the assumed network. It shows that the first year would demonstrate a loss for all the aircraft types. This is to be expected as the cost is high when a new aircraft is introduced to an airline for the first year, but then the costs would come down and stabilize at a given rate. , After 15 to 20 years, the cost would go up due to aging and increasing maintenance.

After 5 years, the model shows a decrease in cost and an increase in profit, and therefore revenue is generated.

Figure 3 - Study Results



## 6. CONCLUSION

Aircraft efficiencies and contribution to profile share have been duly identified. It was learnt from observations in Figure 2 that Embarer Aircraft EMB 170 provides the highest cost per seat mile and the lower individual trip cost. The B717 aircraft on the other hand has the lowest seat/mile cost. The Airbus A318-200 was found to have the highest trip cost but a low seat/mile liability.

Further deeper analysis in Figure 3 have confirmed that the best choice for a given flight operational network the highest profit would be recovered from at least 5 EMB 170 aircraft. This fleet of 5EMB 170 aircraft are also provide the best flexibility. B717 aircraft appear to show the least profit.

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# AVOIDING THE PREDICTABLE SURPRISE: EARLY ACTION IS THE KEY TO BUILDING A CLIMATE-RESILIENT AVIATION NETWORK

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## ABSTRACT

Impacts of climate change, such as sea level rise, higher temperatures and greater weather extremes create an operational, financial and business risk for European aviation. However these are risks which the sector can work to avoid by taking early, and cost-effective, action. A growing but limited number of stakeholders are already implementing comprehensive resilience measures. Yet, a survey of European aviation organisations shows that although awareness is growing many stakeholders are still not acting, often due to a lack of information and guidance. Five key recommendations have been developed to promote cost-effective climate resilience within the sector. These include local and network-wide risk assessment, better use of MET information and the implementation of 'no-regrets' or 'win-win' measures which also address issues such as capacity. Overall, climate change is an issue of risk management and early action is the key to cost-effective mitigation of those risks.

Keywords: climate change, risk assessment, stakeholders

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## 1. INTRODUCTION

A predictable surprise is “an event that leads an organization or nation to react with surprise, despite the fact that the information necessary to anticipate the event and its consequences was available” (Bazerman, 2006, p.179). A recent example is the US sub-prime mortgage crisis. In theory, decision-makers had access to all the information which they needed to predict and prevent it occurring. And yet they failed to act (Watkins, 2007). Climate change is another often cited example. Scientific evidence that our climate is changing is now beyond doubt. Many parts of the world are already experiencing increasing temperatures, altered precipitation patterns and more frequent and more intense extreme weather events (see EEA, 2012; IPCC 2007). Without significant reductions in global carbon dioxide emissions such changes will become more severe and all sectors of global society will be affected. Given this consensus, the requirement to reduce vulnerability and increase resilience to climate change impacts would seem to be obvious. Yet many sectors have yet to initiate comprehensive action to address these risks.

This article will explore the extent to which the European aviation sector is building resilience to the predictable surprise of climate change. It is based on work carried out by EUROCONTROL, the European Organisation for the Safety of Air Navigation, as part of its Challenges of Growth 2013 (CG13) study<sup>1</sup>. The article presents a summary of the study's findings. It will first set out an overview of the potential impacts of climate change for the European aviation sector. It will then review the results of the stakeholder consultation, held as part of the CG13 work, in order to give an indication of the extent to which the European aviation sector is taking action to build resilience to those impacts. Finally it will present a set of recommendations intended to promote the development of climate resilience both within individual organisations and across the European network.

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<sup>1</sup> Challenges of Growth is a series of studies intended to provide decision-makers with the best-achievable set of information to support long-term planning decisions for aviation in Europe, with a particular focus on the capacity of the air transport network. Studies were completed in 2001, 2004, 2008 and 2013. They are available from <http://www.eurocontrol.int/articles/challenges-growth>.

## 2. BACKGROUND

EUROCONTROL first identified the impacts of climate change as a potential operational and financial risk to European aviation as part of its Challenges of Growth 2008 (CG08) environment report (Thomas *et al*, 2009). Following this, three case studies were commissioned to explore possible outcomes in more detail and to examine gaps and weaknesses in the current understanding of aviation's potential climate change risk. The case studies focussed on three climate change impacts which were identified as potentially significant for the European aviation sector: climate-driven changes in demand, sea-level rise and increased extreme weather. Each case study included modelling and analysis of the climate change-related risks and potential impacts for European aviation over a 2020-2090 timescale (see Thomas and Drew, *eds.* 2010).

Subsequent work, such as that of the two European Union Research Framework Programme 7 projects *EWENT* and *WEATHER*, as well as studies carried out by individual aviation organisations, reinforces the findings of EUROCONTROL's initial work and contributes to developing a broad understanding of what the key impacts for the aviation sector will be (see Doll *et al*, 2011; LHR, 2011; Molarius *et al*, 2012; SCVV, 2007).

Therefore, with this basic understanding established, the climate change resilience work for the EUROCONTROL Challenges of Growth 2013 report had two objectives:

- to update the 2008-2010 work on identifying the potential impacts of climate change for the aviation industry and the resulting resilience measures which may be required, and
- to gather stakeholder views as to whether the industry now considers adaptation actions are necessary, and what actions they are taking.

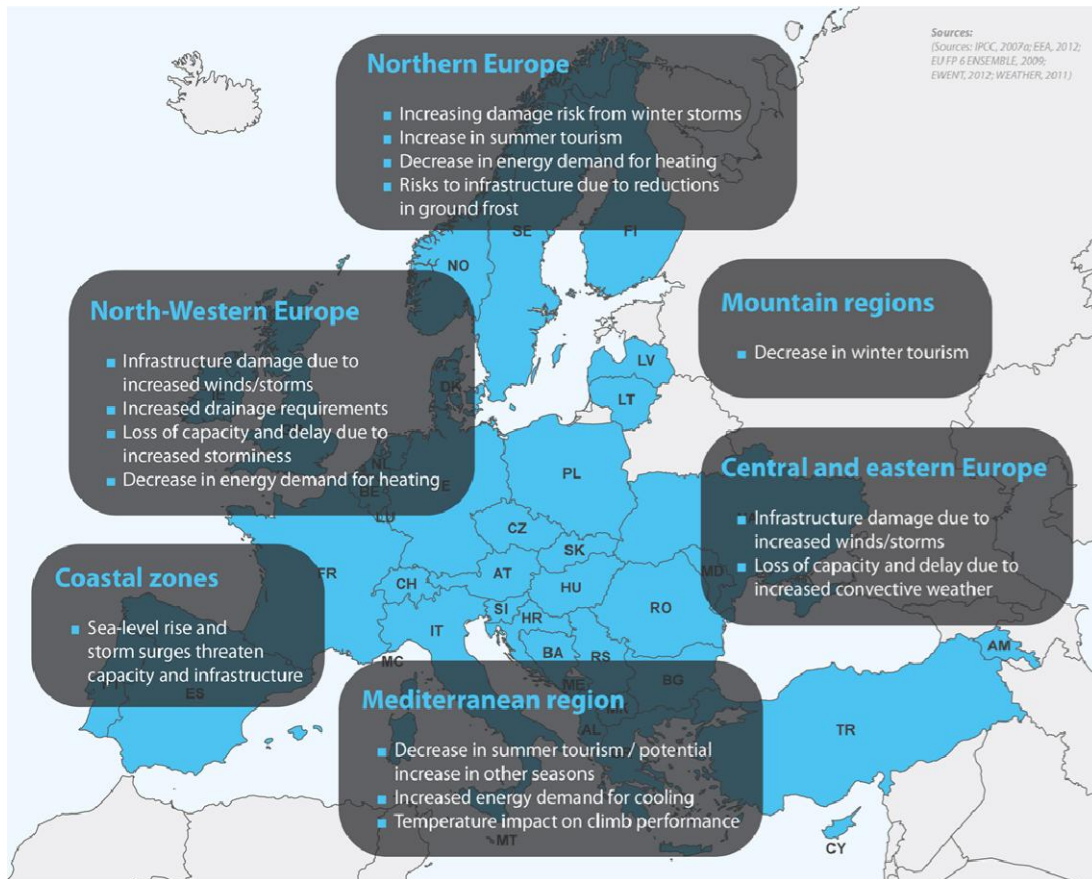
The results of the two tasks could then be combined to assess the extent to which European aviation is already preparing for the impacts of climate change, and to develop a set of recommendations to facilitate the further development of local and network-wide resilience.



### 3. POTENTIAL CLIMATE CHANGE IMPACTS FOR EUROPEAN AVIATION

There is now broad agreement on the qualitative issues that will be faced by European aviation, namely: increased summer heat and humidity in the Mediterranean Basin impacting the amount and location of demand; increased frequency and intensity of storm systems and snow events disrupting operations; and, mean-sea level rise threatening coastal airports and thus network capacity. Such impacts will affect infrastructure, operations and operating costs. However, these impacts will vary according to existing regional climate, geographical location and scale of operation (Figure 1).

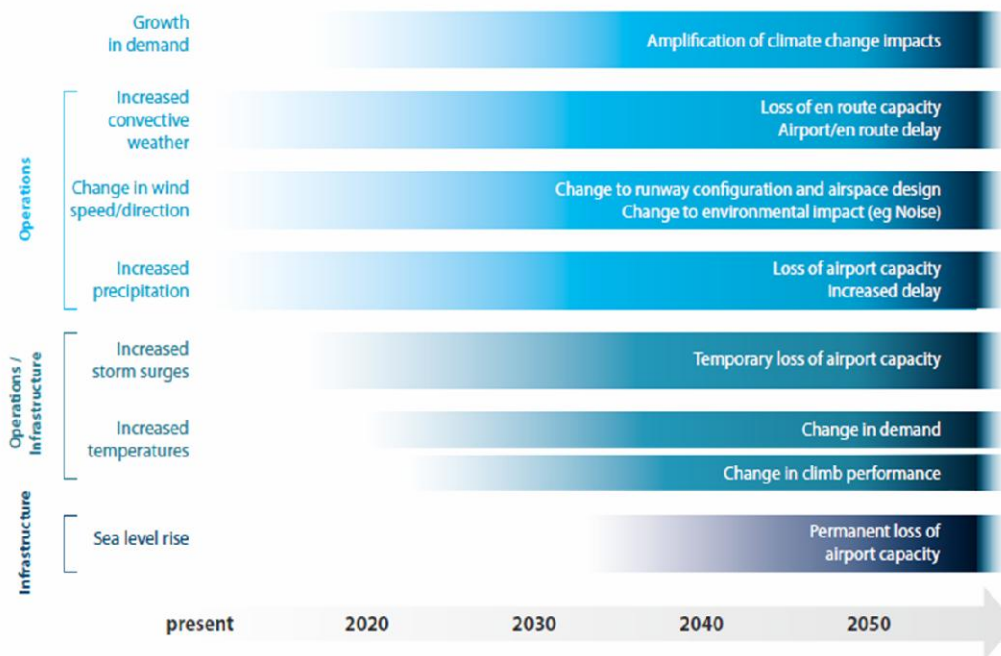
Figure 1 - Potential vulnerabilities and opportunities of climate change



Timescales will also vary, whilst impacts can be both intermittent and persistent. This will affect the resilience measures which are required (Table 1). Impacts such as sea level rise and temperature increase will be experienced persistently but gradually, allowing for longer term planning which can be based on cost benefit analyses if, for example, it needs to be decided whether to protect an airport from rising seas or relocate it. However, intermittent disruptive weather impacts such as heavy

precipitation events or convective weather will be experienced in the shorter term and require resilience measures which can be applied in anticipation of the situation (Figure 2).

Figure 2 - Time line of expected impacts



*NB. This is a broad indication which does not account for regional differences nor future emissions trajectories/climate sensitivity. Timescales are based on analysis for Europe and may vary for other regions. Sources: IPCC 2007b; Thomas et al 2008; Thomas and Drew (eds) 2010; SESAR 2012 Analysis: EUROCONTROL, Challenges of Growth, 2013*

Heavy precipitation events or more powerful and more frequent storms can lead to temporary loss of capacity and increased delays, especially if multiple hub airports in a region are affected. Heavy snow in unexpected locations can have a particularly large effect on airport operations due to the relative lack of preparedness. Moreover, the impact of disruptive weather can be exacerbated when airports are operating close to capacity. Consequently, busier airports may experience more significant disruption. As well as shifts in average climatic conditions, extreme conditions such as very hot or very cold temperatures, can be expected to become greater and last for longer, increasing operational challenges. Moreover, some impacts, such as changes to aircraft performance due to increased temperatures or changes in procedures due to a shift in local wind direction, may incur an additional environmental risk due to the redistribution of noise impact around airports, possibly constraining their ability to grow.

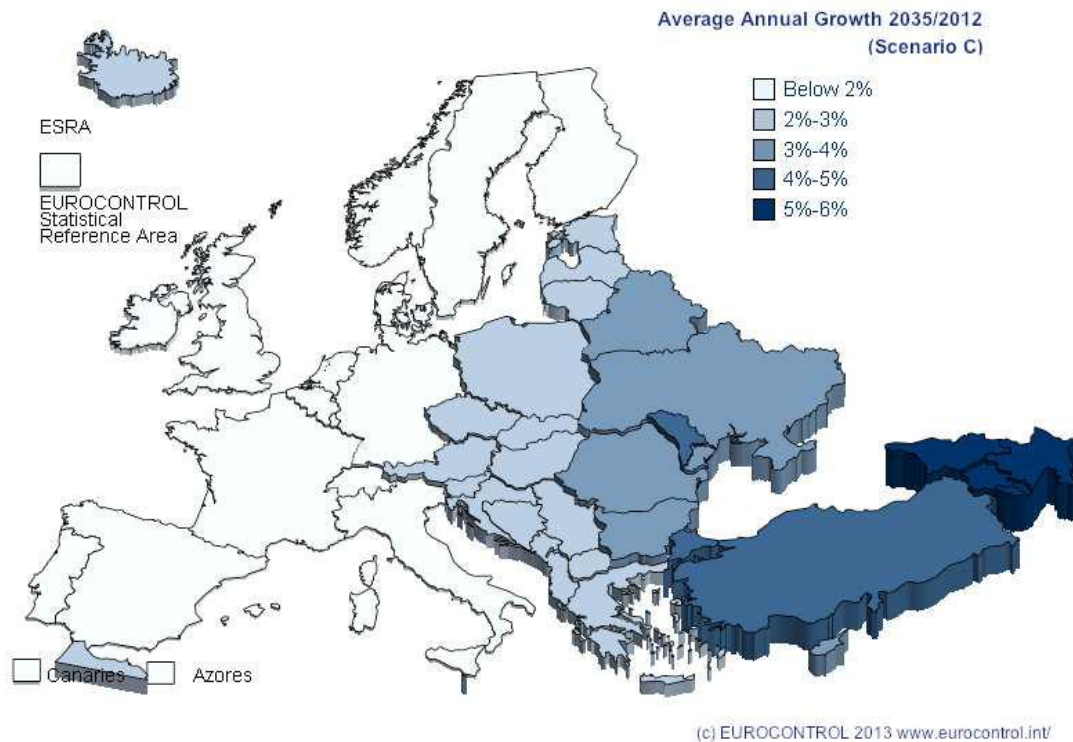
Table 1 - Overview of key climate change impacts and resilience measures identified

	Impact				
	Temperature increase	Changes to precipitation (rain and snow)	Increase in intensity and frequency of convective weather	Changes in Wind patterns	Sea level rise
<b>Potential impact for aviation</b>	Changes in demand Changes in climb performance Redistribution of noise impact Heat damage to tarmac surfaces	Operational impacts: loss of capacity and efficiency. Increased delay. Increased de-icing requirements. Increased pressure on drainage systems. Structural issues due to changes in ground frost depth and duration	Operational impacts: loss of capacity and efficiency. Increased delay.	Increased crosswinds and loss of runway capacity Redistribution of noise impact due to procedural changes	Loss of network capacity, increased delays, network disruption. Temporary or permanent airport closure
<b>Type of impact</b>	Persistent	Intermittent	Intermittent	Intermittent	Persistent
<b>Approximate timescales</b>	>20 years before impacts become serious	< 20 years but potentially much sooner	< 20 years but potentially much sooner	< 20 years but potentially much sooner	>40 years before impacts become serious
<b>Potential resilience measures required</b>	<ul style="list-style-type: none"> <li>• Research to understand potential demand shifts</li> <li>• Review of infrastructure and personnel requirements (+/-)</li> <li>• Airspace redesign</li> <li>• Community engagement</li> </ul>	<ul style="list-style-type: none"> <li>• Operational improvements to increase robustness and flexibility</li> <li>• Improved use of MET forecasting</li> <li>• Information sharing (SWIM)</li> <li>• Training</li> <li>• A-CDM</li> </ul>	<ul style="list-style-type: none"> <li>• Operational improvements to increase robustness and flexibility</li> <li>• Onboard technology for weather detection</li> <li>• Improved use of MET forecasting</li> <li>• Information sharing (SWIM)</li> <li>• Training</li> <li>• A-CDM</li> </ul>	<ul style="list-style-type: none"> <li>• Local risk assessments</li> <li>• Operational improvements to increase robustness and flexibility</li> </ul>	<ul style="list-style-type: none"> <li>• Operational improvements to increase robustness and flexibility</li> <li>• sea defences</li> <li>• development of secondary airports</li> </ul>
EUROCONTROL, Challenges of Growth 2013. <i>Timescales are based on analysis for Europe and may vary for other regions</i>					

A potentially significant risk, which is still poorly understood from an aviation perspective, is the potential change in traffic demand patterns due to climate-related changes in both tourist destination preferences and global supply chains. The Mediterranean region currently attracts around 100 million visitors from Northern Europe each year (Amelung and Moreno, 2009). The CG08 Case Study on climate change and traffic demand estimated that 73% of tourist arrivals to Greece were by air (Dimitriou and Drew, 2010). Of course, some but not all Mediterranean destinations are more easily accessible from Northern Europe by other modes of transport. Yet, this still suggests that even relatively small numbers of tourists who fly to the Mediterranean during the summer months deciding to travel to alternative destinations could lead to significant changes in infrastructure and staffing requirements at both traditional and potential new destinations. More positively, if a proportion of those tourists decide to change their habits and travel to traditional holiday destinations in the spring or autumn months instead of the customary summer period, then this could ease congestion during the traditional peak season. Although such issues will seldom be isolated from other factors affecting demand, it is important to understand their potential impacts, particularly when investing in long-term infrastructure projects.

Furthermore, despite the current global economic crisis, overall aviation demand is expected to continue to grow in coming years, putting increasing pressure on operations in both emerging and established markets. However, this growth in demand is not expected to be distributed equally, with some states with emerging markets potentially experiencing up to 5-6% average annual growth (Figure 3). Further, some of the areas where the highest growth is predicted, such as South East and Central Europe, are also some of the areas where the greatest potential climate change impacts are predicted. Consequently, such states may have to cope with growing demand whilst dealing with climate change impacts such as water stress or increased extreme weather. Moreover, as the impacts of disruptive events such as convective weather or heavy precipitation can be exacerbated when capacity at an airport is constrained, it is essential to build resilience at locations which may experience both high growth in demand and significant impacts from climate change.

Figure 3 - Forecast annual average annual growth in European traffic  
2035/2012



#### 4. EUROPEAN AVIATION STAKEHOLDER CONSULTATION

The second part of the CG13 work consisted of a stakeholder consultation carried out in two stages; the first part was an online survey for operational stakeholders<sup>3</sup> to investigate whether the industry now considers adaptation actions are necessary, and what actions they are taking. This was followed by a one day stakeholder workshop open to operational stakeholders, decision-makers, and the research community.

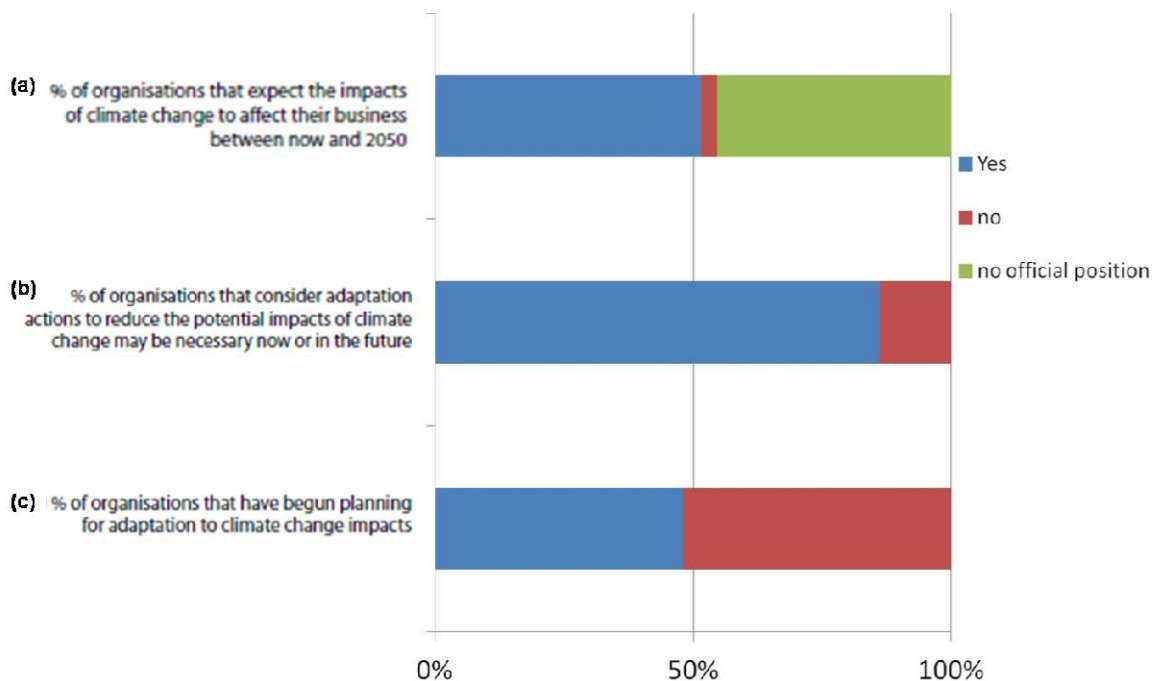
The survey was sent to approximately 100 organisations and 35 valid responses were received. The majority of respondents were either ANSPs or Airport Operators. No responses were received from aircraft operators. This may be due to aircraft operators' shorter planning horizons, because this is not yet an issue on their agenda, or because we did not reach the correct people in individual organisations. However, it does represent an important gap in our knowledge. In terms of

<sup>3</sup> Air navigation service providers (ANSPs), airport operators, aircraft operators, civil aviation authorities and industry associations in Eurocontrol Member States.

geographical spread, responses were received from all of the main European climate zones.

The survey identified that just over half of respondents now consider climate change will be a risk for their organisation between now and 2050 with just under half not yet having an official position ( $N = 33$ , Figure 4a). For those that do not currently have an official position it was suggested that the risks had not yet been assessed or it was not yet on their long-term agenda. This is a shift in opinion from four years ago when very few organisations had begun to address the issue. However, despite many organisations not yet having an official position, over 80% of respondents do consider that resilience measures to adapt to climate change will be necessary now or in the future ( $N = 29$ , Figure 4b). The main climate change impacts which stakeholders expect to be affected by are more incidences of extreme weather such as storms, an increase in precipitation (rain and snow) and higher temperatures. A potential change to predominant wind directions was also a recurring concern. For those that did not think it will be necessary to take action the main reasons were because they do not expect to experience significant impacts or because the risks have not yet been assessed.

Figure 4 - Percentage of respondents who (a) expect to be impacted by climate change by 2050; (b) consider adaptation to climate change will be necessary (c) have begun adaptation planning

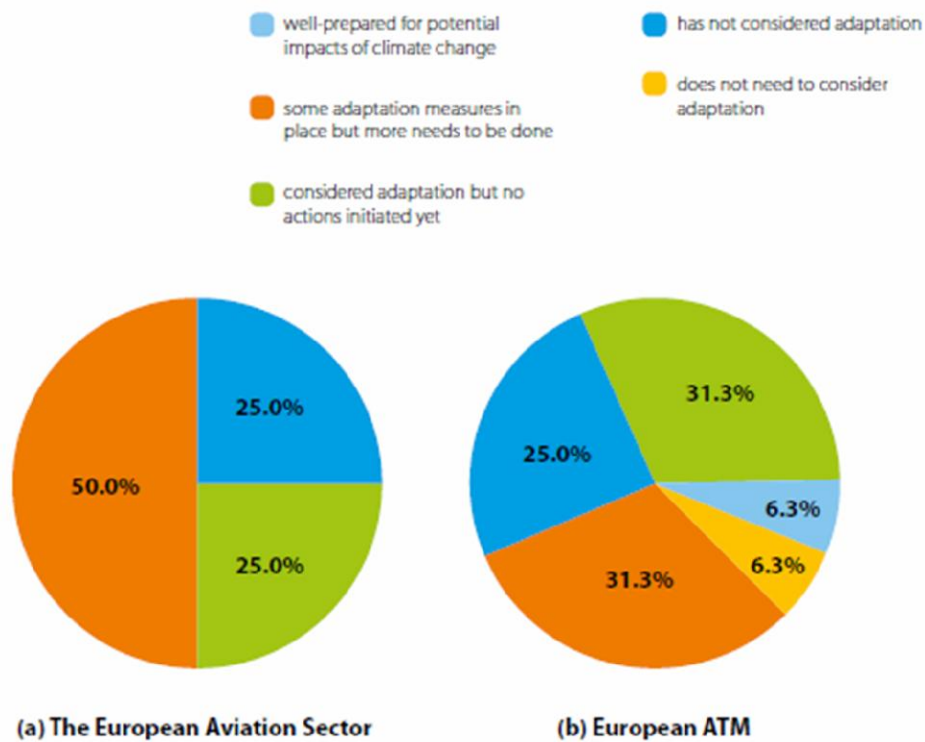


Sources: EUROCONTROL, *Challenges of Growth*, 2013



Yet, despite this growing awareness of potential impacts, less than half of organisations that responded have begun planning for adaptation ( $N = 25$ , Figure 4c). Some organisations feel it is too early whilst others feel they do not have enough information or resources. Of those that have begun planning, only four respondents had produced adaptation plans. When respondents were asked their opinion as to the current adaptation status of the European aviation industry 50% thought that some adaptation measures were in place but more needs to be done 25% thought that adaptation had been considered but nothing concrete had been done yet and another 25% thought that adaptation has not yet been considered ( $N = 16$ , Figure 5a).. When asking specifically about ATM, that rose to a third with just a third thinking that some adaptation measures are in place ( $N = 16$ , Figure 5b).

Figure 5 - Stakeholder perception of level of preparedness for the potential impacts of climate change for (a) the European Aviation Sector as a whole (b) European ATM



Source: EUROCONTROL, *Challenges of Growth*, 2013

Overall, the results indicated that a growing number of organisations expect to need to take action to adapt to the potential impacts of climate change, but that this is still an emerging issue, with a perceived lack of information and guidance. It should also be kept in mind that the results may demonstrate a certain amount of self-selection

in that organisations which are already experiencing an increase in incidences of disruptive weather, or who are already implementing measures to adapt to climate change, may have been more likely to respond to the survey. In order to gain a clearer picture of the current status of climate change adaptation for the European aviation industry, it would be necessary to carry out a more strategic state by state analysis of vulnerabilities, resilience measures being implemented and action gaps.

Following the survey, a one day workshop was held at EUROCONTROL Headquarters in Brussels. Participants represented 20 organisations including airport operators, air navigation service providers, the Single European Sky ATM Research programme (SESAR, industry associations, the academic community and European policy makers. Participants concluded that there is a growing need for climate change risk assessment and planning for adaptation measures. However, concerns were expressed about acquiring financial resources for something which may not be within immediate planning horizons. To address this issue it was proposed that no-regrets solutions, measures which are already being implemented to address other issues such as capacity but which also contribute to building climate resilience, and low-cost actions such as training should be identified. The next section will consider how these proposals can be translated into concrete action to build climate resilience.

## 5. BUILDING CLIMATE RESILIENCE

Despite geographical variations in impact, there is now broad agreement as to the challenges which will be faced. This knowledge should be used as the basis to take action to identify adaptation measures which develop resilience to those impacts. Following the constructive discussions during the workshop, we have developed a set of five key resilience measures which the sector should consider.

### *a. Assessment of gaps and vulnerabilities for the sector at local, regional and global levels*

Risk assessment and resilience planning are required at both network and local levels. Indeed, due to the interconnectedness of the regional and global aviation systems, an integrated approach to building resilience is essential to ensure that vulnerabilities in one part of the network do not exacerbate impacts in other parts. During the peak of 2012's Hurricane Sandy, 8-9% of global airline capacity was



grounded leading to lost revenues conservatively estimated at around US\$0.5 billion (IATA, 2012). An increase in such events will have a significant operational and financial impact. Therefore, even if one part of the global integrated transport system is fully protected against such risk, the overall network is still vulnerable if another vital part does not take the necessary action.

*b. Identification and implementation of local, regional and global resilience measures, particularly no-regrets measures such as operational improvements*

Early action to address climate change is widely agreed to be cost-effective (EC, 2013; EEA, 2013). Therefore now is the time to proceed with implementation. In particular, 'no-regrets' or 'win-win' measures can contribute to reducing the costs of building long-term climate resilience. For example, measures which are intended to build greater weather resilience and facilitate operations in adverse conditions, address issues such as capacity, or improve infrastructure can be cost and resource efficient solutions.

Moreover, the interconnectedness of the global aviation network suggests that a holistic approach which integrates local and regional impact assessments and resilience planning may be required. Resilience measures should also be coordinated with other parts of the transport network, including ground transport access to airports, so as to reduce overall vulnerability to the maximum extent possible.

*c. Identification and implementation of cost-effective measures such as training*

Some of the cheapest and potentially most effective ways to build resilience are staff training, sharing of best practices, experiences and solutions, and the implementation of processes which facilitate collaborative responses to climate change challenges. Moreover, whilst situational and meteorological information flows are vital (see below), people still need to be trained in how to use the information. Training in how to respond to the actual disruptive weather itself is also required.

*d. Increased collaboration with MET Services to better exploit advanced forecasting techniques*

Good MET information combined with proactive responses can improve operational resilience. Improved MET support is now available to ATM to enable better advance planning. Probabilistic forecasting can identify potential weather issues several days

in advance and models can now run at a much higher resolution than previously. Trials have demonstrated that effective proactive planning responses to severe weather can produce significant performance gains in adverse conditions compared to unstructured reactive responses which could reduce capacity and compromise safety margins. This means that decision-making needs to be built on confidence in good meteorological information and an understanding of what those conditions mean in practice.

*e. Analysis of the potential impacts of climate change on air traffic demand to inform medium and long-term operational and business planning*

Several studies have now been completed which analyse the potential impacts of climate change for tourist preferences (see EEA, 2012). However, as yet, only limited work has been done to translate those changes of preferences into potential changes of demand for aviation (see Dimitriou and Drew, 2010). Therefore the potential impacts of climate change on traffic demand and its interaction with other economic and social factors could be better understood. It would be prudent to instigate further work to examine any possible trends. The results of such studies could then be used to inform medium and long-term operational and business planning. Other factors such as the implications that climate change may have for en-route capacity would also benefit from greater understanding, whilst the more general consequences of a changing climate, such as potential changes in wind vector, need to be translated into specific local impacts. Therefore, whilst implementing concrete measures to build resilience to those impacts which have already been identified should not be delayed, it would be judicious to carry out further specific analyses at both local and network level.

## 6. EARLY ACTION TO BUILD RESILIENCE

Despite indications that climate change adaptation is still a low priority for European aviation as a whole, some stakeholders are already taking comprehensive action. EUROCONTROL in its role as Network Manager<sup>4</sup> has been working in partnership with

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<sup>4</sup> The ATM Network Manager is a function established by the European Commission to optimise the performance of the aviation network in Europe. The Network Manager brings together the different aviation and air traffic management actors involved in the design, planning and management the European ATM network. EUROCONTROL was appointed as the Network Manager in 2011. <http://www.eurocontrol.int/dossiers/network-manager-new-key-role-european-aviation>

air navigation service providers, airports and airlines to re-enforce the operational management of adverse weather conditions, both en-route and at airports. This has involved measures such as the implementation of procedures to facilitate planning, coordination and communication during disruptive events, as well as to proactively manage demand. On the other side of the Atlantic, the FAA has developed a programme to build infrastructural and operational climate resilience.

Also in Europe, the SESAR research programme is developing MET infrastructure and services to integrate improved MET capabilities to European network operations. This increases resilience by promoting better information sharing, which in turn allows for more proactive and flexible responses to disruptive weather events. Some individual organisations have also begun to take action. For example, the Norwegian Airport operator and ANSP, Avinor, has recently introduced guidance stipulating that runways should not be built lower than 7 metres above sea level whilst implementing an extensive programme to increase wave and storm surge protection at coastal airports. And whilst relatively few organisations have developed climate change adaptation plans, those that have been put in place tend to be comprehensive (see LHR, 2011; MAG, 2011).

However, as the *Challenges of Growth* stakeholder consultation demonstrates, many organisations have either yet to consider this issue, or do not have the knowledge and resources to act. This suggests that more data, information and guidance are required, and that climate adaptation needs to be addressed collaboratively as an industry. Moreover, it should not be forgotten that there is a financial implication to this preparedness; cost-benefit analyses will be required to determine what level of impact it is feasible to cope with.

## 7. CONCLUSIONS

The potential impacts of climate change on the aviation industry will vary according to location and scale of operation, and may be further exacerbated by the challenge of accommodating increased growth in demand. The impacts and consequences for European aviation can already be anticipated and, at a high-level, many potential measures to mitigate those impacts are either already being implemented, or at least have been identified. Cost-effective climate adaptation can be achieved by building

resilience into current infrastructure and operations planning and identifying cheap and no-regrets measures such as training. This suggests that the predictable surprise can be avoided.

Yet, the *Challenges of Growth 2013* stakeholder consultation demonstrates that many organisations are not yet taking action. In many cases this is due to lack of information or guidance. Moreover, aviation is a global industry and vulnerabilities in one part of the network can translate into costs and operational impacts for other parts. Therefore, we need to communicate and collaborate at all levels in order to implement resilience measures as efficiently and effectively as possible. Overall, climate change is an issue of risk management and early action is the key to cost-effective mitigation of those risks. Therefore, if we want to avoid a predictable surprise the time to act is now.

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