A STUDY ON THE RELATIONSHIP BETWEEN AIRPORT PRIVATISATION AND AIRPORT EFFICIENCY

AN APPLICATION OF USING AHP/DEA METHODS

A thesis submitted in fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

in

CARDIFF UNIVERSITY

by

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April 2013

≈ DECLARATION AND STATEMENT ≈

DECLARATION

This work has not previously been accepted in substance for any degree and is not concurrently submitted in candidature for any degree.

Signed Po-Lin Lai

Date 10 April 2013

STATEMENT 1

This thesis is being submitted in partial fulfilment of the requirements for the degree of PhD

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Date 10 April 2013

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This thesis is the result of my own independent work/investigation, except where otherwise stated.
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ABSTRACT

In order to deal with the competitive environment surrounding the air transport industry, civil aviation authorities have undertaken several approaches to improve airport efficiency, such as investing in the infrastructure and privatising airport ownership or governance. Among these methods, airport privatisation policy has been implemented for around 25 years in the U.K., closely followed by other European countries. By contrast, decision makers elsewhere, such as in the Asia-Pacific region, are now interested in privatisation and in doing so evaluate the impact of this process elsewhere. Therefore, the primary aim of this research is to examine the relationship between airport privatisation and efficiency, through an Airport Efficiency Evaluation System (AEES). The study covers Europe and the Asia-Pacific region, reflecting different attitudes towards the role of government within airport management.

Focussing on the most popular method for assessing airport efficiency, with Data Envelopment Analysis (DEA) a unit can appear efficient simply because of its pattern of inputs and outputs rather than any inherent efficiency. But only using DEA may not provide useful results about the efficiency of airports as different decision makers may weight the relative importance of inputs and outputs differently (for example, airport managers, and airline companies). In this research, another aim is to develop and demonstrate the applicability of different analysis techniques within the AEES. For this reason, Analytic Hierarchy Process (AHP) analysis is adopted to calculate the importance of each variable. These results are then integrated into both DEA and DEA, Assurance Region (AR) models, to reflect the different importance of the metrics. In the context of air transportation, an integrated AHP/DEA and AHP/DEA-AR model are applied for the first time to evaluate airport efficiency. A sensitivity analysis with different variable sets is carried out.

In conclusion, an AEES is established and the result shows that the approach by adopting AHP/DEA-AR model in particular can provide more accurate values of relative efficiency than using the traditional DEA approach. There are also different priorities between stakeholder groups and these can affect the efficiency scores of airports. However, the results for each of the different analysis techniques show that there is no statistically significant relationship between airport ownership and efficiency.

ACKNOWLEDGEMENTS

First and foremost, I would like to express my greatest appreciation to my supervisor, Dr. Andrew Potter, who has always been patient, generous and encouraging to me throughout this long journey. I will be forever in his debt. I would like to express my sincere gratitude to Professor Malcolm Beynon and Professor Anthony Beresford for their invaluable comments and suggestions on my research. My special thanks also to Professor John Doyle and Professor Kevin Cullinane for their suggestions and comments in the viva.

It is a pleasure to thank the participants of the questionnaire survey of this research. Without their time and patience, this thesis would not been completed. I wish to thank Professor Chin-Shan Lu and Dr. Chung-Shan Yang for their kindly support not only on academia but also on my life in Cardiff. Also my thanks also go to all the supporting staff, especially: Penny, Elaine, Elsie, Lainey and Sara.

I wish to thank my friends, Poti, Champ, Wan, Seayon, Hyunmi, Jane, Virginia, Suhan, Suneerat, Qinyun, Ko-Yang and many others for providing fuel for my brain and for their warm friendship in Cardiff.

From the bottom of my heart, I am grateful to my parents, my elder brother, and uncle John, whose unconditional support and love has provided me with this lifetime opportunity. Without their spiritual support, this research would not have gone this far. Last but not least, thanks to lovely wife Janice for her continuous support and endless sacrifices. Without her love and understanding, I think I cannot finish this research.

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CHAPTER 1

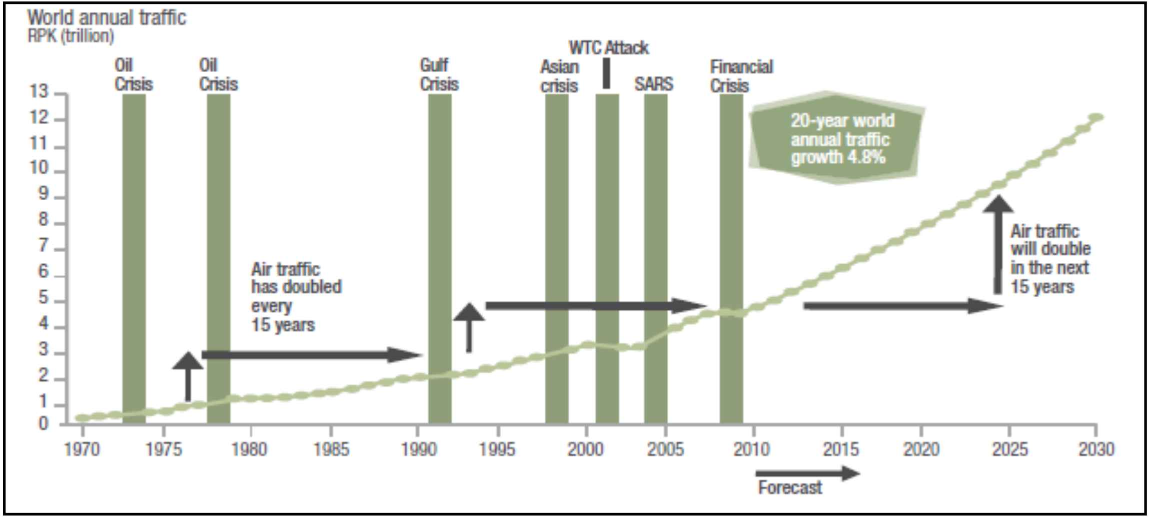
INTRODUCTION

An overview of the research is presented in this chapter. It outlines the challenges of the research intends to solve, explains why these issues are interesting to explore, and describes how these issues are addressed. The first section presents the introduction and motivation. The second section presents the research objectives and research questions. The third and fourth sections illustrate the structure and contributions.

1.1 INTRODUCTION AND MOTIVATION

Air transport is tightly connected with a country's economic development; this has been especially true since the globalisation of most modern economies. Figure 1.1 illustrates the increase in global air travel since the 1970s. It can be seen that air transport has faced several external exogenous events (such as the Gulf crisis in 1991, the Asian crisis in 1998, the War on Terrorism in 2001, the SARS international health crisis in 2003, and the financial crises of 2008), as well as more medium to long term challenges (oil price surges, airport congestion, and competition with high speed train networks). Although the performance of the air transport industry was affected by these events, air transport still grew at a yearly average of 4.2% from 1990 to 2010. It should be noted that from 2004 and 2010, the Revenue Passenger Kilometers (RPKs) rebounded quickly after the above events, increasing 14% in 2004 and 7% in 2010 (Airbus 2012).

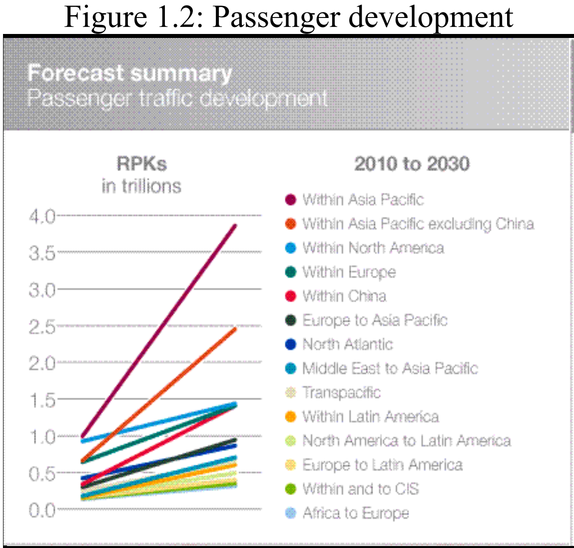
Figure 1.1: World annual air traffic



Source: Airbus (2012).

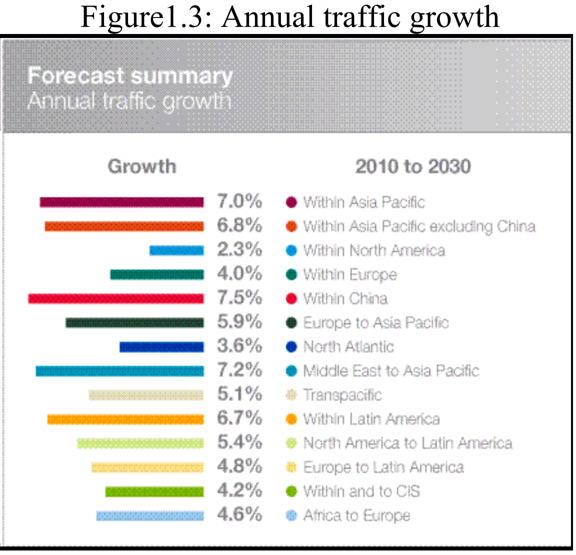
According to a recent forecast report produced by Boeing in 2012, air transport will double in the next 20 years, and the centre of the world air transport flow is expected to move towards the Asia-Pacific region. More than one third of the value of new airplanes delivered will be accounted for by this region, compared with about a quarter for North America and a quarter for Europe. Figures 1.2 and 1.3 illustrate the projected growth of passengers and traffic in different world regions over the next 20 years. Figure 1.2 shows that the Asia-Pacific region, specifically China, will become the principal air transport market. Although the growth rate of North America, Europe, and the CIS[1] are lower than that of the Asia-Pacific, these areas will still maintain their growth rate because of the increased airline competition brought about by deregulation and liberalisation, which has heightened this recognition and placed airports in a much more competitive environment (Barros and Dieke 2007). Further, Figure 1.3 shows that traffic flow has experienced a trend similar to that of passenger flow.

Figure 1.2: Passenger development



Source: Boeing (2012).

Figure1.3: Annual traffic growth



Source: Boeing (2012).

Among all participants in the air transport industry, such as carriers (airline companies and logistics or rail companies) and loading points (such as airports, warehouses, distribution centres, and seaports), airports are the core of the air transport industry due to their provision of the logistics of both passenger and cargo services. The most rapidly developing economies of the world have enormous requirements for advanced air transport facilities at their airports in order to accommodate the increasing volumes of air transport in the areas of cargo and passenger services and in order to sustain their operational efficiency in places such as the Asia-Pacific region. In order to deal with increasing levels of competition, recently, performance measurement has become an important means by which civil aviation authorities can determine weaknesses, especially in those regions facing increasing volumes of air transport in both cargo and passenger services (Oum et al. 2008).

Under intense global market competition, many countries have explored different long-term options to maximise efficiency or productivity in regard to operation and resource

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[1] The CIS includes Russia and the Commonwealth of Independent States.

utilisation, including such things as reforming existing airports (e.g. Taipei Taoyuan Airport), building new airport terminals (e.g. Beijing, London Heathrow, and Istanbul airports), or privatising airport management (e.g. London airports). Among these options, privatising airport management is one of the ways to help governments to reduce budget barriers, which will in turn contribute to profits. Therefore, in Europe, airport privatisation policies have been used to improve airport efficiency and resource utilisation for almost 25 years including even full airport privatisation.

Recently, there has been less progress with privatisation of airports in Asia compared to other regions of the world because from their viewpoint it would be more cost effective to restructure public sector enterprises and attempt to turn them around before instituting privatisation (Joshi 2000). Even though some airports in the Asia-Pacific region are listed on the stock exchanges (i.e. six Chinese airports: Shenzhen, Shanghai, Xiamen, Hainan, Beijing, and Guangzhou airports), full airport privatisation is still not the first option for many authorities in the Asia-Pacific (Zhang and Yuen 2008). Partially privatised airports may be restructuring for privatisation, but the government still controls the majority shares of those airports. In addition, the lack of a consistent privatisation policy also leads to failure to consider different ways for the private sector to participate as well as a consideration of the relative effectiveness of such alternatives in regard to achieving a given set of objects (Vickers and Yarrow 1991). This is the most significant difference existing in the implementation of airport privatisation policies in these two regions (i.e. Asia-Pacific and Europe).

However, Zhang and Yuen (2008) pointed out that public listing does not significantly improve airport productivity in China. After reviewing relevant studies, Gong et al. (2012) also revealed that airport industries did not provide clear patterns of superior performance associated with particular forms of ownership or organisation. This is quite different from the common opinions of privatisation. Therefore, one of the aims of this research is to determine if an airport privatisation policy can really help airport authorities improve airport efficiency. To achieve this aim, establishing a proper Airport Efficiency Evaluation System (AEES) is the first task of this research.

In this research, Data Envelopment Analysis (DEA) and an Analytic Hierarchy Process (AHP) are applied to establish the AEES. DEA can help to recognise relative efficient airports. However, only using DEA may not provide robust results about the efficiency of airports because stakeholders may weight the relative importance of input and output variables differently. For example, airport managers may focus on financial performance, but civil aviation authorities (i.e. the public sector) may place emphasis on the number of passengers or aircraft movements. Therefore, another aim in this research is to develop and demonstrate the applicability of an integrated DEA and AHP evaluation model for addressing this concern. AHP can help researchers outline the preferences of different stake holders (i.e. airport managers or airport analysts). In addition, two means are adopted in this research by addressing sensitivity analysis. Firstly, basic DEA models, an integrated AHP/DEA model, and an AHP/DEA with Assurance Region (AR) method are used to evaluate airport efficiency. Secondly, adjusting the number of variables in the DEA analysis is also adopted as the sensitivity analysis in this research. The sample airports in this research are selected from Europe and the Asia-Pacific region as a result of reflection on their different attitudes towards the role of the government in airport management and also because these two regions are currently the most competitive areas with regard to air transport. According to the author's best ability, in the context of air transportation, an integrated AHP/DEA model and an AHP/DEA-AR model are firstly applied to evaluate the efficiency of the airports under consideration.

1.2 RESEARCH QUESTIONS

This research can make some theoretical and methodological contributions. Therefore, there are two main types of research questions that can be addressed in this research, including theoretical research questions and methodological research questions. Theoretical research questions are listed in the first section.

One of the aims of this research is to establish an AEES. Interest in this topic has prompted a substantial body of research utilising both qualitative and quantitative approaches. Many of the quantitative approaches calculate efficiency frontiers with an assumption that all the input and output variables are assumed as having the same weight (such as Gillen and Lall 1997; Murillo-Melchor 1999; Bazargan and Vasigh 2003; Wang et al. 2004). However, it has been shown through qualitative research that different stakeholders may place greater emphasis on particular variables (Humphreys and Francis 2002b). Such an emphasis can be captured through the AHP method and incorporated into efficiency evaluations. In this research, airport efficiency is evaluated using three methods (i.e. basic DEA models, an integrated AHP/DEA model, and an AHP/DEA-AR model). Therefore, the first research question should be addressed as follows:

Research Question 1:

Does the result of airport efficiency vary as a result of conducting different evaluation methods?

Another aim of this research is to determine if airport privatisation influences airport efficiency. Privatisation of their airports is one of the popular means adopted by many civil aviation authorities to improve efficiency. This strategy was first implemented in the United Kingdom about 25 years ago (Ison et al. 2011) and has since been adopted by other western industrialised countries, such as Germany and the Netherlands. However, most of the major airports in Asia are still operated and owned by the government or quasi-public enterprises. Therefore, another research question to be addressed in this research is:

Research Question 2:

Would an airport privatisation policy (airport ownership) influence the performance of an airport's operational efficiency?

The research questions in the following section can be classified as methodological research questions in this research. In the AHP method, a series of pairwise comparisons and the unit scale used in its procedure play a fundamental role in quantifying a decision maker's preference judgements. To date, the Saaty 1-9 scale is the 9-unit scale which has been used widely in AHP research. However, the AHP literature has addressed the question of which of the available alternative scales are more appropriate for the process of pairwise comparisons (French 1980; Freeling 1983; Jensen 1984; Legrady et al. 1984; Belton 1986; Harker and Vargas 1987; Schoner and Wedley 1989; Dyer 1990; Salo and Hämäläinen 1993; Pöyhönen et al. 1997; Beynon 2002). Therefore, the third research question of this research is:

Research Question 3:

Does the influence of alternative scales on the results of the AHP analysis cause a different weight for each variable?

The DEA model was first proposed by Charnes et al. (1978) and was subsequently extended by Banker et al. (1984). It is now widely applied for measuring the efficiency of many entities, such as schools, public agencies, and banks, among others. (Giokas 1991; Anderson et al. 1998; Oum and Yu 1994). During recent years, the issue of both the sensitivity and stability of DEA models has been extensively studied. By updating the inverse of an optimal basis matrix, Charnes et al. (1985) discussed the sensitivity of the original DEA model. Also, Charnes and Neralic (1990) investigated the sensitivity of the DEA-additive model and proposed different models to find the stability radius for an efficient DMU. This research intends to introduce DEA sensitivity analysis by adjusting a given number of input and output variables and by adopting different DEA models to undertake and evaluation of airport efficiency. This analysis can help determine which number of variables or which DEA model can provide the most robust results. Therefore, the fourth research question is:

Research Question 4:

Does the number of input and output variables affect the results of airport efficiency evaluation?

1.3 THE SCOPE AND STRUCTURE OF THE RESEARCH

This research primarily examines the impact of airport privatisation policy on airport efficiency via sample airports selected from the Asia-Pacific region and Europe (the reasons are explained later) and also is an attempt to provide the answers to the above mentioned research questions. It is structured into nine chapters, as follows:

Chapter 1 introduces the subject area of the research, including a basic background, motivation, objectives, scope, research questions, and the structure of the research. The chapter also concludes with possible research contributions of the research for academics, practitioners and policy makers.

Chapter 2 presents a structured literature review that encompasses airport performance studies. In addition, theories and disciplines involved in airport performance research are investigated. In addition, changes in research trends are examined in order to understand the positioning of this research in the periodic trends of airport research.

Potential analysis techniques that can be used in this research are described in detail in this chapter as well.

Chapter 3 reviews the changing nature of airports in order to understand the categories of airport ownership and governance, illustrates the evolution of airport ownership and governance, and justifies the differences between diverse countries. Airport privatisation policies are described that are related to Research Question 2.

Chapter 4 examines the technical considerations of the current research development. This chapter connects the previous chapters to the following chapters that develop the research philosophies applicable to this study. This research adopts the positivist paradigm for the purpose of understanding airport performance by using different analysis methods. Choice of methodological approaches, such as research philosophy, research strategies, survey tool selection, data collection methods, and research design are examined. This chapter also describes the data analysis methods that are employed in this research. In this chapter, the characteristics and processes for the AHP, DEA, and the integrated AHP/DEA model are illustrated. The definitions of alternative scales for AHP analysis are listed, which can be used to answer Research Question 3.

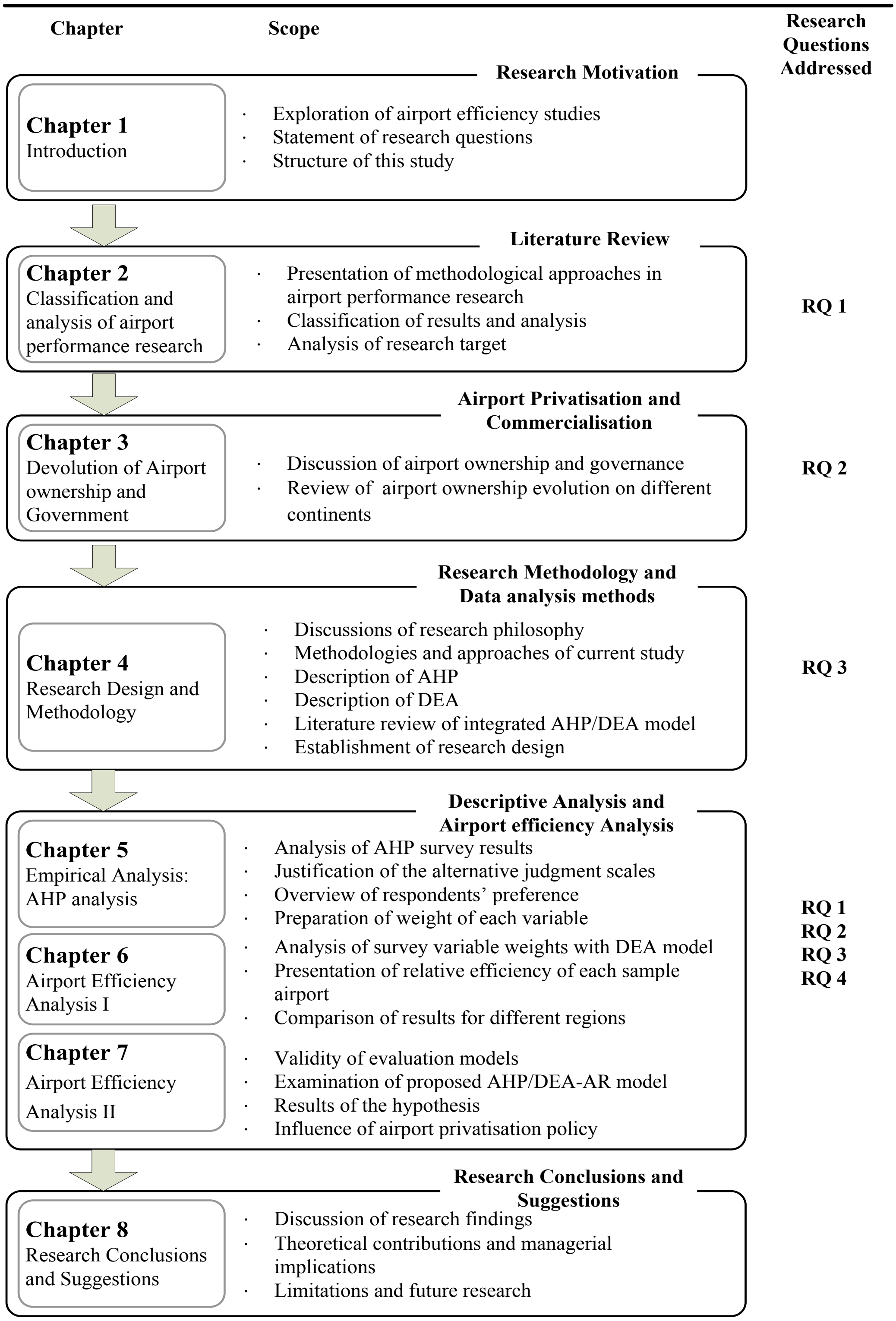
Chapter 5 addresses the results of the pilot AHP questionnaire and the complete AEES used in this research is confirmed. Along with variables sets, the AHP method is used to acquire the weights of variables in 1-9 scales and other alternative scales. An overview of the relative weights of variables and classification of different groups are also listed. The chapter ends with a brief summary of the descriptive analysis for this research.

Chapter 6 shows the empirical results of the model through implementation of the variable weights discussed in Chapter 6. Prior to the analysis of the measurement models, the collected data are examined and prepared. After the data preparation processes, each DEA model is validated and purified through a series of analytical processes. Finally, the results are examined and a discussion of the proposed hypotheses is provided. After hypothesis testing, the results can be applied to confirm the impact of airport privatisation policies. In this chapter, airport efficiency analysis is computed using a basic DEA model and an integrated AHP/DEA model. One of the sensitivity analyses is also conducted in this chapter (i.e. different numbers of input and output variables).

Chapter 7 conducts another sensitivity analysis by applying the AHP/DEA-AR model to assess airport efficiency. The concepts and analysis process for this model are described, and airport efficiency is also computed based on different numbers of variables. In this chapter, the results are examined and a discussion of the proposed hypotheses is provided. After hypothesis testing, the influence of airport privatisation policy is confirmed, and the results are also compared with those of Chapter 6. The results acquired from Chapters 6 and 7 can help the author to provide proper answers to the research questions. At the end of this chapter, different thoughts on efficiency evaluation approaches and hypothesis testing methods are also presented.

Chapter 8 concludes the research with an overall summary and a discussion of the key findings. Finally, the thesis presents a description of the theoretical, methodological contributions, and the managerial implications of this research, along with some limitations and recommendations for future research. Figure 1.4 illustrates the research structure and highlights the scope of each chapter, its context, and the links between the chapters.

Figure 1.4: Structure of the research



	Chapter	Scope	Research Questions Addressed
Research Motivation	**Chapter 1** Introduction	· Exploration of airport efficiency studies · Statement of research questions · Structure of this study	
Literature Review	**Chapter 2** Classification and analysis of airport performance research	· Presentation of methodological approaches in airport performance research · Classification of results and analysis · Analysis of research target	**RQ 1**
Airport Privatisation and Commercialisation	**Chapter 3** Devolution of Airport ownership and Government	· Discussion of airport ownership and governance · Review of airport ownership evolution on different continents	**RQ 2**
Research Methodology and Data analysis methods	**Chapter 4** Research Design and Methodology	· Discussions of research philosophy · Methodologies and approaches of current study · Description of AHP · Description of DEA · Literature review of integrated AHP/DEA model · Establishment of research design	**RQ 3**
Descriptive Analysis and Airport efficiency Analysis	**Chapter 5** Empirical Analysis: AHP analysis	· Analysis of AHP survey results · Justification of the alternative judgment scales · Overview of respondents' preference · Preparation of weight of each variable	**RQ 1** **RQ 2** **RQ 3** **RQ 4**
	Chapter 6 Airport Efficiency Analysis I	· Analysis of survey variable weights with DEA model · Presentation of relative efficiency of each sample airport · Comparison of results for different regions	
	Chapter 7 Airport Efficiency Analysis II	· Validity of evaluation models · Examination of proposed AHP/DEA-AR model · Results of the hypothesis · Influence of airport privatisation policy	
Research Conclusions and Suggestions	**Chapter 8** Research Conclusions and Suggestions	· Discussion of research findings · Theoretical contributions and managerial implications · Limitations and future research	

1.4 RESEARCH CONTRIBUTIONS

Broadly, this research aims to provide a better understanding of airport privatisation policy and also to establish a robust AEES, with a particular focus on Europe and the Asia-Pacific region, as well as to identify the importance of different variables in AEES. The core of the research is based on perspectives of Europe and Asia-Pacific experts. In detail, using a combination of theoretical and practical perspectives, this research would like to:

- Build a theoretical system of airport efficiency evaluation.
- Employ different evaluation methods to recognise a holistic and robust airport efficiency evaluation model.
- Adopt the AHP/DEA model and AHP/DEA-AR model in airport efficiency evaluation in the first place.
- Understand the privatisation of airport governance and ownership.

It is hoped that this research will provide significant contributions to academics and practitioners in the airport management sector.

- For **academics**, an improved AEES understanding of links between academia and practice and a new evaluation model established from different viewpoints should emerge.
- For **practitioners**, the identification of the variables affecting airport operations, explored in this study, may stimulate more considered transport decision-making by providing a more accurate and precise framework for airport planning.

CHAPTER 2

ANALYSIS OF AIRPORT PERFORMANCE RESEARCH

This chapter aims to review existing literature that is related to this research in order to first provide a context for the undertaken research and to show where this research fits into the existing body of knowledge; secondly, to illustrate what kind of topics have been studied previously; thirdly, to outline differences between existing studies, and finally, to justify the existing studies on this topic.

2.1 MOTIVATION

Airport performance measures are important to business and operations management, regulatory bodies, governments, and other stakeholders (Humphreys and Francis 2002b). Airport managers and governments evaluate airport performance for a number of reasons, including the assessment of financial and operational efficiency, the evaluation of alternative investment strategies, the monitoring of airport activities from a safety perspective, and for the purpose of monitoring environmental impact (Doganis 1992). In the mid-1990s, the literature on efficiency evaluation, which had already been applied to numerous industries (for example, electricity, water, banking, health, and agriculture) (Giokas 1991; Bureau et al. 1995; Ozcan and McCue 1996; Zang and Bartels 1998), was introduced to the airport sector.

To follow this trend, a number of relevant studies have been published in the past 20 years although the level of interest in aviation has still been relatively modest as compared to other industries, with the range of approaches applied reflecting a lack of consensus in determining the methods that best define the complex reality of the airport industry. The primary objective of this chapter is to examine how airport performance evaluation research has been conducted. This chapter takes a methodological perspective and, as such, considers the broad range of performance variables present in the literature. This includes aspects such as finance, operations, service quality and the environment. To achieve this, a structured review of published airport performance evaluation literature for the last two decades (1990-2012) was undertaken.

2.2 METHODOLOGICAL APPROACHES

The research on airport performance can be classified into two main types: efficiency evaluations and productivity evaluations. The main difference between efficiency and productivity evaluations lies in the concept of maximum attainable outputs (Oum and Yu 2004). Efficiency takes the maximum potential output that can be produced, and it takes the available inputs into account, while productivity considers the actual outputs. Therefore, efficiency often relies on comparisons with other Decision Making Units (DMUs). However, the terms efficiency and productivity are often used interchangeably even though the underlying meanings of these two terms are not identical. The fact that changes in productivity are due to changes in efficiency, among other factors, may have had an influence in considering both terms as equivalent (Zhu 2009). In order to evaluate efficiency and productivity, previous studies usually have adopted quantitative methods, relying on numerical and secondary data. They also have formulated production functions using econometric techniques and advanced efficiency analysis tools, such as those applied in studies by Sarkis (2000) and Martin et al. (2009). A theoretical overview of the main approaches is provided as follows:

2.2.1 PARTIAL MEASURES

This method uses partial ratio data to carry out performance comparisons of a target sample in a single dimension, such as financial or cost performance. It deals with the ratio of one output to the ratio of one input in order to assess efficiency or productivity with respect to a specific dimension. It does not give any conclusions on the overall efficiency (Forsyth 2000). Since the partial measures method only focuses on certain fields of airport performance, it is relatively easy to calculate and interpret. However, the evaluation results from this method are not able to provide a more comprehensive evaluation of an airport's performance unless they is a part of a broad performance measurement system. This approach also has other weakness. As discussed by Forsyth (2000), partial measurement should only be used if no data for overall measures are available.

2.2.2 MULTI-CRITERIA DECISION MAKING (MCDM)

The Multi-Criteria Decision Making (MCDM) method establishes preferences between options by reference to an explicit set of objectives that have been identified by the decision making body and for which it has established measurable criteria intended to assess the extent to which the objectives have been achieved. In simple circumstances, the process of identifying objectives and criteria may provide enough information alone for decision makers. Historically, employing the MCDM method can be divided into two main steps: acquiring the relative weights for each criterion and ranking the options. The first stage often uses expert questionnaires or interviews to evaluate the selected variables, providing the weights to choose an optimal solution (Roy 2005).

The most widely used method in the MCDM is AHP, which was developed from a linear additive model but, in its standard format, uses procedures for deriving the weights and the scores achieved by alternatives which are based, respectively, on pair-wise comparisons between criteria and between alternatives. Thus, for example, in assessing weights, the decision makers are asked a series of questions, each of which asks how important one particular alternative is relative to another for the object being addressed. The strengths and weaknesses of AHP have been the subject of substantial debate among specialists in the MCDM (for example, French 1980; Freeling 1983; Jensen 1984; Legrady et al. 1984; Belton 1986; Harker and Vargas 1987; Schoner and Wedley 1989; Dyer 1990; Saaty 1990; Salo and Hämäläinen 1993; Pöyhönen et al 1997). It is, however, clear that users generally find the pair-wise comparison form of data input straightforward and convenient.

The other methods which are used in the MCDM include:

- PROMETHEE (Preference Ranking Organisation Method for Enrichment Evaluations), which was proposed by Brans and Mareschal (2005) and which defines preference functions based on the differences between criteria among different schemes (Hu et al. 2010).
- TOPSIS (Technique for Order Preference by Similarity to Ideal Solution), which was proposed by Hwang and Yoon (1981). This uses ideal and anti-ideal solutions to find the best alternative. It assumes that each indicator takes a monotonic function (increasing or decreasing) utility (Wang et al. 2004 and Hu et al. 2010).
- ELECTRE (Elimination and Choice Expressing Reality), which was developed by Benayoun et al. (1966) and improved by Roy (1971; 1991). The ELECTRE methodology has evolved through a number of different versions (I through IV). ELECTRE I is designed for choosing a single action, while ELECTRE II, III and IV deal with ranking. The subset containing all the most satisfying alternatives is obtained by eliminating the greatest number of alternatives (Bojkovic et al. 2010).

2.2.3 FRONTIER ANALYSIS

Three main methods which have been adopted by scholars to analyse efficiency are: Stochastic Frontier Analysis (SFA), Total Factor Productivity (TFP), and Data Envelopment Analysis (DEA). Although these methods are similar in that they determine a frontier and an inefficiency based upon that frontier, which is the efficient frontier, there is a significant difference between them. Although SFA estimates inefficiency, it can also be used as an explanation for inefficiency (Pels et al. 2003).

Furthermore, the DEA approach provides a measurement of inefficiency. A brief description of each method is given below:

2.2.3.1 STOCHASTIC FRONTIER ANALYSIS (SFA)

SFA models were first proposed by Aigner et al. (1977); they have since been used extensively in scientific literature. In recent years, several alternatives have been proposed in the literature to relax the restrictive assumption that all DMUs share the same technological parameters. For example, Kalirajan and Obwona (1994), Tsionas (2002), Huang (2004) and Greene (2005) developed different versions of random coefficient models which are based on SFA, in which differences between DMUs (i.e. heterogeneity) are modelled in the form of continuous parameter variations. More recently, Kumbhakar et al. (2007) developed a non-parametric stochastic frontier using a local maximum likelihood approach.

In 2005, Greene proposed two alternative panel data estimators that the author labelled as true random effects and true fixed effects. The main feature of Greene's (2005) model is that a time-invariant DMU effect co-exists with inefficiency in order to avoid the inefficiency term picking up a DMU's heterogeneity. In addition, the true random effects model (which assumes that there is a DMU-specific random term to capture DMU heterogeneity) has been used widely. On the other hand, the true fixed effects model assumes that the DMU-specific term is a fixed parameter and is allowed to be correlated with the included variables. Although these parametric approaches take into account the effect error, they still face challenges with regard to separating random error from efficiency.

2.2.3.2 TOTAL FACTOR PRODUCTIVITY (TFP)

Total Factor Productivity (TFP) is determined by how efficiently and intensely the inputs are utilised in production. In other words, it is the portion of output not explained used in production (Comin, 2006). TFP requires an aggregation of all outputs into a weighted output index. It also requires that all inputs be placed into a weighted input index using pre-defined weights, which can be biased. The key drawback of the TFP technique is that it does not allow for random error in the data, assuming that measurement error and luck are factors that affect outcome. This implies that the measured inefficiency is likely to be overstated (Berger and Humphrey 1997).

Moreover, it constructs a frontier based on the actual data in the sample, and the relative efficiency of each DMU in the population is calculated in relation to this frontier. Therefore, the result may be very sensitive to the chosen sample and the outliers.

2.2.3.3 DATA ENVELOPMENT ANALYSIS (DEA)

DEA requires no assumptions about the functional form and calculates a maximal performance measure for each DMU relative to all other DMUs. DEA was originally developed by Charnes et al. (1978) by applying a linear programming technique that converted multiple inputs and multiple outputs into a scalar measure of relative productive efficiency to construct a frontier based on the sample. DMUs on the frontier are efficient, while DMUs inside the frontier are inefficient. With the assumption of no random errors, all deviations from the estimated frontier are attributed to inefficiencies.

Both non-parametric methods (DEA and TFP) compare a weighted output variable relative to a weighted input variable. However, the key advantage of DEA is that the input and output weights result from a linear programming procedure rather than being pre-determined (Graham 2005). DEA is often a more attractive technique when compared with the other two methods because of its less demanding data requirements. In general, the main motivation for choosing DEA is often its flexibility with regard to accounting for multiple input/output variables in the estimation of efficiency (Banker 1984). This method can also account for external factors that are related to the environment in which a particular DMU operates. One of the method's major weaknesses is that it has no statistical properties and, hence, does not account for measurement error in the estimation of efficiency (Charnes et al. 1985). The use of DEA can become even more problematic in the presence of outliers, which can simply distort the derived efficiency results (Russell 1985).

Recently, the bootstrapping method, which is one of the DEA approaches, is a computer-based method for assigning measures of accuracy to sample estimates (Efron and Tibshirani 1994) has became popular. This technique allows estimation of the sample distribution of almost any statistic using only very simple methods (Varian 2005). Generally, it falls in the broader class of resampling methods. In addition, Network Data Envelopment Analysis (NDEA) is currently emerging as a way of evaluating the efficiency of sub-processes within the overall system (Kao 2009).

2.3 LITERATURE ANALYTICAL DISCIPLINES

This section describes the results of a structured literature review about the air transport field which has been carried out to confirm the existent research gaps, which is a new approach to adopt in airport performance evaluation research. A structured literature review is a means of identifying, evaluating and interpreting all available research which is relevant to a particular research question, topic area, or phenomenon of interest. Individual studies contributing to a structured review are called primary studies; a structured review is a form of secondary study (Armitage and Keeble-Allen, 2008). In this research, only papers published in academic journals are included for content analysis in this chapter. Other reports published by research institutions (such as the annual Global Airport Benchmarking Report published by the Air Transport Research Society or other industry reports), airport authorities (individual airport performance report) or the government sector (annual reports) were not included. Moreover, conference papers, news reports, book reviews, viewpoints, master and doctoral dissertations, textbooks, and unpublished working papers were also excluded. The reason why this research only includes academic papers is because most academic papers are published under a serious trial process. Therefore, their results tend to be more reliable than those found in other reports. In addition, a structured literature review was undertaken in this research. It is very difficult to construct a structured procedure to review industry reports due to the large number of items. Besides, no specific data base can include most industry reports, and it is difficult to narrow down these kinds of reports. An example can help to show how tough it is to track non-academic publications. If one uses the search term “airport efficiency” in a Google search engine, there are more than 200,000 items that can be found. Therefore, only academic papers were included in this literature review.

The main search terms in the survey were ‘airport’ with ‘efficiency’, ‘performance’, or ‘productivity’, and the end of June 2012 was selected as the cut-off date. Various online journal databases were selected and searched to provide a comprehensive bibliography on airport performance evaluation literature. The literature contributions included articles from the following research databases: Emerald, Science Direct (Elsevier), ProQuest Global, Google scholar, and SCOPUS. These databases provide online delivery systems with full text access to thousands of high quality articles and journals that cover a wide range of social and applied science titles, including business and management disciplines. However, some journals may be beyond the scope of these databases, and therefore, their contributions may not be included in the results. The search yielded 66 airport performance evaluation articles from 23 journals. Details of these can be found in Appendix I and in the bibliography. Each article was carefully reviewed, and the data was organised to produce a classification from several perspectives. Consequently, this research serves as a comprehensive base for an understanding of airport performance evaluation research.

The classification framework is based on the literature review, the nature of airport performance evaluation research and the work of Gonzalez and Trujillo (2009) and Pallis et al. (2010) (who have conducted studies in a similar field related to (sea) port efficiency). The articles were reviewed, analysed, and classified based on four perspectives, as follows:

(1) Distribution by year of publication and methodology;
(2) Distribution of articles by journal;
(3) Geographical distribution of airport performance research; and,
(4) Analysis of input and output variables.

This framework provides guidelines for pursuing rigorous airport performance evaluation research by explaining the chronological growth of the benchmarking technique, challenging themes of airport performance evaluation research and application areas in airport performance evaluation.

2.3.1 DISTRIBUTION BY YEAR OF PUBLICATION AND METHODOLOGY

Table 2.1 shows the distribution of 66 articles published between 1990 and June of 2012. It reveals that only limited papers were published on this topic before the year 2000. The first recorded paper was published in 1997. However, Graham (2005) highlighted a small number of non-journal publications that preceded this date. In the past ten years, the number of journal articles has increased significantly. This growth trend is quite similar to the early trends in (sea) port performance evaluation although (sea) ports have been studied over a longer period, leading to more than one hundred articles evaluating their performance (Gonzalez and Trujillo 2009; Woo et al. 2010). This suggests that there is a potentially rich continuous flow of research in the air transport field for many years to come especially in this year (2012).

Table 2.1: Analysis methods used in airport performance evaluation

	1997	*1998*	*1999*	*2000*	*2001*	*2002*	*2003*	*2004*	*2005*	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*	***Total***
Partial Measures	-	-	-	1	-	1	-	-	-	-	-	-	-	-	-		**2**
MCDM	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-		**1**
Frontier Analysis																	
Parametric Approach																	
SFA	-	-	-	-	-	-	-	-	-	-	-	2	1	1	1	1	**6**
Non-Parametric Approach																	
DEA	1	-	2	1	2	1	2	3	-	1	1	3	2	2	2	3	**26**
TFP	1	-	-	-	-	-	1	1	-	1	-	1	-	-	1	1	**8**
Combination*	-	-	-	-	1	1	1	1	-	1	-	1	1	3	1	4	**15**
Other Research Methods	-	-	-	-	-	1	-	1	-	1	-	-	2	2	1	1	**9**
Total	**2**	**0**	**2**	**2**	**3**	**4**	**4**	**7**	**0**	**4**	**1**	**7**	**6**	**8**	**6**	**10**	**66**

* Combinations include: DEA and TFP; DEA and SFA; and SFA and TFP.
Source: Organised by author.

Only two papers adopted the partial measures method to evaluate airport efficiency between 1990 and 2012. Francis et al. (2002) revealed that most traditional airport financial performance measures were based around a Work Load Unit (WLU), defined as one passenger processed or 100kg of freight handled. In the 1980s, this measure was taken from the airlines and adopted by airports to provide a single measure of output for both the passenger and freight business. Typical measures used included total cost per WLU, operating cost per WLU, and labour cost per WLU. A deeper discussion of the measures (including details on a number of publications which lie beyond the scope of the method adopted in this thesis) can be found in Graham (2005). A recent example of the application of this approach can be found in the Competition Commission's investigation into the BAA in the UK (Competition Commission 2008).

MCDM approaches have also seen very limited applications in the context of airport efficiency. The only example is Wang et al. (2004), who used TOPSIS to evaluate the operational performance of Taiwan's major airports. PROMETHEE have seen no applications that has been confirmed in Behzadian et al. 2009. AHP applications within aviation generally have focused on airport logistics (Tsai and Su 2002) and hub airport allocation (Berrittella et al. 2009), but not on airport efficiency evaluation (the use of online journal databases in this study has been previously described). Several key papers are listed as follows: Tsai and Su (2002) used AHP to compute the relative weights and to identify the critical political risk factors that influenced the development of an air logistics hub in Taiwan. Yoo and Choi (2006) conducted an AHP analysis of surveyed data about the relative importance of the factors and elements concerned with the improvement of passenger screening. Berrittella et al. (2009) developed an application of AHP to rank the operating cost components of full service and low cost airlines; however, in this particular study, AHP was not used in the context of efficiency/performance evaluation, and it was not combined with DEA. Castelli and Pellegrini (2011) used AHP to assess the opportunity of implementing this concept by considering the views of experts. These findings indicate that there are some net benefits for airlines and air navigation service providers who use AHP, but not for airports. From the above brief review, according to the author's knowledge, currently there has been no paper published that has attempted to combine AHP with DEA in the area of air transport.

Furthermore, DEA is the most popular method that is used when evaluating airport performance, producing a steady flow of research throughout the time period under examination. Twenty-six papers were found that used DEA to evaluate airport performance from the point of view of the airport authorities. Although Adler and Berechman (2001) also used DEA, they chose the airlines' viewpoint to analyse airport quality and performance. TFP has also been used in occasional publications, such as the regular Global Airport Benchmarking report. Meanwhile, Hooper and Hensher (1997) were the first researchers to use TFP, examining the performance of six Australian airports over a four year period. More recently, between 2008 and 2012, the SFA has been used as an individual method in six papers. Oum et al. (2008) and Barros (2008b) were the first two papers that adopted SFA to evaluate airport efficiency. Oum et al. (2008) evaluated the effects of ownership form on airport cost efficiency by applying SFA on the world's major airports. Barros (2008b) used a random stochastic frontier model to estimate the technical efficiency of UK airports. Moreover, the bootstrap approach in the DEA context has been widely adopted in the past few years (Assaf 2010; Curi et al. 2010; 2011). In 2011, Assaf also used the Malmquist bootstrapped combined methodology to assess the extent of productivity, efficiency, scale and technological changes at the major Australian airports. In 2012, there was a new method applied to evaluate airport efficiency called the Bayesian dynamic frontier model. Assaf et al. (2012) applied this model to assess UK airport efficiency. Assaf and Gillen (2012) adopted this model to combine with SFA to compare the efficiency of 73 international airports. Finally, combinations of methods and other approaches have also seen a small but regular flow of publications (e.g. Pels et al. 2001; Martin and Roman 2006 and Yang 2010). However, these combinations have focused on bringing together different (objective) frontier analysis techniques, rather than bringing in the subjectivity of the MCDM (Wang et al. 2004). As outlined earlier, the motivation behind this research is to overcome the relative weaknesses of individual methods. However, after reviewing all of the papers on this topic, it was found that most of the previous studies on airport performance measurement have failed to consider other important variables that can influence an airport's performance evaluation, such as the characteristics of airport authorities and airport users (e.g. airline companies or passengers).

2.3.2 DISTRIBUTION OF ARTICLES BY JOURNAL

A total of 23 different journals from various subjects (including urban planning, operations management, economics, and transportation) published airport performance articles in the target period. Table 2.2 illustrates that the vast majority of articles (i.e. 37 articles, or 56% of the total) were published in just two journals, which are: *Journal of Air Transport Management* (JATM) and *Transportation Research Part E* (TRE). The list of the articles published shows that publications in the TRE represent the first publications of particular analytical approaches (or combinations of them) in the context of airport efficiency, such as Gillen and Lall (1997) for DEA, and Hooper and Hensher (1997) for TFP. By contrast, the publications within the JATM tend to contain papers that focus more on the applications of these techniques. All of the analysis methods in Table 2.1 have been applied across the 24 papers in the JATM. This concentration of publications within a limited number of sector-specific publications is similar to that occurring with regard to port efficiency (see Gonzalez and Trujillo 2009; Woo et al. 2010). This concentration of publications in a limited number of journals does have some advantages since it means that there is a solid body of research which is relatively easy to locate, while these journals clearly appear to be natural homes for airport efficiency publications. However, there is a danger that this research may become quite insular and lacking in impact, or that it draws inspiration from other research outside of the air transport sector. Looking forward, the findings here suggest that researchers should consider a broader range of journals for publications to ensure that opportunities from other disciplines can be exploited.

Table 2.2: Distribution of airport performance articles by journal

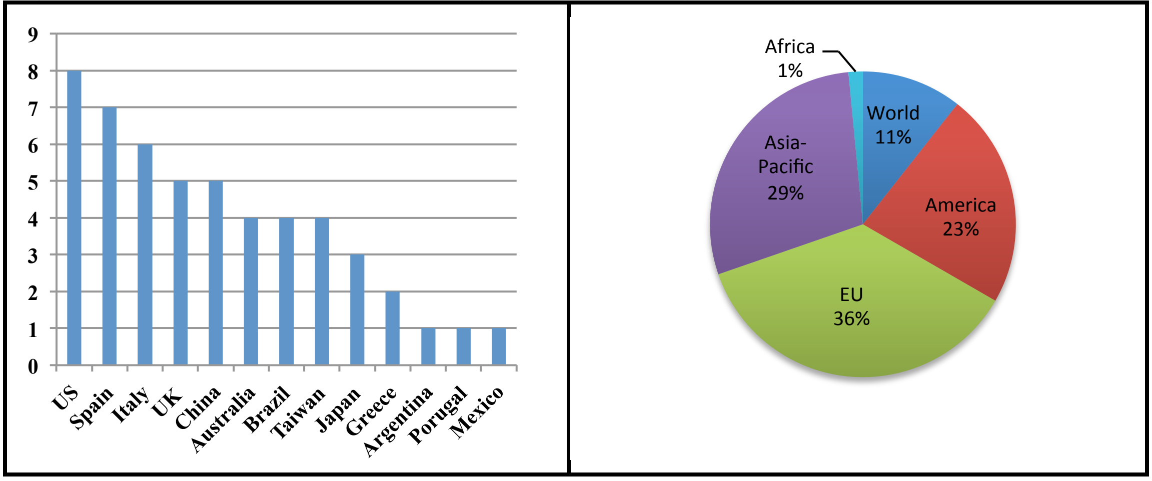
Journal Title	**Author Name and Published Date**	
The Australian Economic Review	Abbott and Wu (2002).	1
Computers and Industrial Engineering	Yang (2010).	1
European journal of operational research	Assaf and Gillen (2012).	1
International Journal of production economic	Gitto and Mancuso (2012b).	1
International Journal of Transport Economics	Murillo-Melchor (1999); Gillen and Lall (2001); Barros and Sampaio (2004).	3
International Journal of Transport Management	Humphreys and Francis (2002b).	1
Journal of Air Transportation	Vashigh and Gorjidooz (2006).	1
Journal of Air Transport Management	Hamzaee and Vasigh (2000); Martin and Roman (2001); Francis et al. (2002); Martin-Cejas (2002); Bazargan and Vasigh (2003); Oum et al. (2003); Wang et al. (2004); Yu (2004); Oum et al. (2006); Lin and Hong (2006); Barros and Dieke (2007); Barros (2008a); Barros (2008b); Assaf (2009); Chi-Lok and Zhang (2009); Manataki and Zografos (2009); Curi et al. (2010); Ablanedo-Rosas and Gemoets (2010); Tsekeris (2011); Chow anf Fung (2012); Gitto and Mancuso (2012a); Scotti et al. (2012); Wanke (2012a); Zhang et al. (2012).	24
Journal of Operations Management	Sarkis (2000).	1
Journal of Productivity Analysis	Martin et al. (2009).	1
Journal of Transport Economics and Policy	Parker (1999).	1
Journal of Urban Economics	Oum et al. (2008).	1
Networks and Spatial Economics	Martin and Roman (2006); Lozano and Gutierrez (2011).	2
Omega	Yu (2010).	1
Pacific Economic Review	Barros et al. (2010); Fung and Chow (2011).	2
The Service Industries Journal	Assaf (2011).	1
Socio-Economic Planning Sciences	Curi et al. (2011); Wanke (2012).	2
Transport Policy	Pels et al. (2001); Barros (2011).	2
Transportation Research Part A	Fernandes and Pacheco (2002); Pacheco and Fernandes (2003); Sarkis and Talluri (2004).	3
Transportation Research Part E	Gillen and Lall (1997); Hooper and Hensher (1997); Pels et al. (2003); Oum and Yu (2004); Yoshida (2004); Yoshida and Fujimoto (2004); Barros and Dieke (2008); Fung et al. (2008); Pathomsiri et al. (2008); Yu et al. (2008); Lam et al. (2009); Tovar and Martin-Cejas (2010); Assaf et al. (2012).	13
Transport Review	Barros (2009).	1
Tourism Management	Assaf (2010).	1
Utilities policy	Perelman and Serebrisky (2012).	1
Total Number of Journals: 23	**Total Number of Papers: 66**	

Source: Organised by author.

2.3.3 DISTRIBUTION OF ARTICLES BY GEOGRAPHY

Figure 2.1 below illustrates the geographical trend in airport performance research. Of these 66 papers, 12% (eight papers)[*] studied airports in the United States (US), while 10% (seven papers)[*] studied Spanish airports. The focus on these countries reflects both the affiliations of those undertaking the research plus the availability of data for analysis. By grouping these papers into continents, it can be seen that 36% (24 papers) attempted to evaluate airport performance in Europe. This survey reveals an interesting point in that only five papers investigated airport performance in South America (Fernandes and Pacheco 2002; Barros 2008a; Perelma and Serebrisky 2012; Wanke 2012a; 2012b). To date, only one paper has investigated African airport performance (Barros 2011). Two reasons behind this are the availability of suitable data for analysis and the relative importance of these areas in the global air transport industry. For future research, there are a considerable number of opportunities for efficiency evaluations in other countries and regions. Further opportunities exist in conducting comparative studies across different regions and, as time progresses, conducting increasingly longitudinal studies in specific countries to evaluate policy changes.

Figure 2.1: Distribution of sample region classified by country and continent



Source: Organised by author.

2.3.4 ANALYSIS OF INPUT AND OUTPUT VARIABLES

Tables 2.3 and 2.4 highlight the degree of diversity in the input and output variables in regard to the research conducted, reflecting previous comments by Yoshida (2004).

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[*] These papers are: Gillen and Lall (1997); Sarkis (2000a); Hamzaee and Vasigh (2000); Gillen and Lall (2001); Bazargan and Vasigh (2003); Sarkis and Talluri (2004); Vashigh and Gorjidooz (2006); Pathomsiri et al. (2008).

[*] These papers are: Murillo-Melchor (1999); Martin and Roman (2001); Martin-Cejas (2002); Martin and Roman (2006); Martin et al. (2009); Tovar and Martin-Cejas (2010); Lozano and Gutierrez (2011).

This section considers these variables in more detail. Ülkü (2009) provided a classification that was based on broad categories of input and output variables. However, this research considers each of these individually, and it also looks at the specific variables used. The following analysis can provide the concepts by which to construct variables in the preliminary AEES.

2.3.4.1 INPUT VARIABLES ANALYSIS

The input variables that have been previously used in airport performance research (Table 2.3) can be divided into two categories: airport service variables (such as the number of employees, gates or length of runway), which were related to the services that were provided by the airport; and financial variables (such as operational cost and capital cost), which were related to financial performance. In the first category of airport service variables, the number of employees (which is an essential variable of production in airport activities) was adopted in almost half of the airport performance papers as an input variable. In addition, the size of the terminal and the number of gates were also widely adopted for use in a large number of studies. Among financial variables, operational cost was the most widely introduced. Generally, most of the studies used between three and eight input variables. As noted by Ülkü (2009), the majority drew their inputs from either airport service or financial variables. Airport service variables were generally more popular, which may be due to data availability, the lack of published financial accounts for airports (especially publicly owned airports), difficulties in reconciling different accounting practices, or currency fluctuations affecting international comparisons. There were two types of approach that were used in studies of service variables. Most authors adopted a counting approach to airport facilities, using values such as the number of runways or the number of gates (Gillen and Lall 2001; Lin and Hong 2006). A few studies considered area instead, with inputs such as area of departure lounge or the area of the apron (Pacheco and Fernandes 2003; Yu 2004). The former approach considers the efficient use of assets while the latter evaluates the efficient use of space. Only a few studies took variables from both service and finance categories (Bazargan and Vasigh 2003). This represents a good opportunity for future research because it is possible to provide a more balanced approach.

Table 2.3: The most popular input variables

Input Variables	Papers	
Airport Service Variables		
Number of employees	Gillen and Lall (1997; 2001); Murillo-Melchor (1999); Parker (1999); Sarkis (2000); Abbott and Wu (2002); Oum et al. (2003; 2008); Barros and Sampaio (2004); Oum and Yu (2004); Sarkis and Talluri (2004); Yoshida and Fujimoto (2004); Lin and Hong (2006); Barros (2008a); Yu et al. (2008); Lam et al. (2009); Martin et al. (2009); Assaf (2010); Barros et al. (2010); Tovar and Martin-Cejas (2010); Yang (2010); Yu (2010); Assaf (2011); Curi et al. (2011); Assaf and Gillen (2012); Perelman and Serebrisky (2012); Scotti et al. (2012).	27
Size of terminal area	Gillen and Lall (1997); Pels et al. (2001; 2003); Fernandes and Pacheco (2002); Pacheco and Fernandes (2003); Oum et al. (2003; 2008); Yoshida (2004); Yoshida and Fujimoto (2004); Yu (2004); Lin and Hong (2006); Barros (2008a); Fung et al. (2008); Chi-Lok and Zhang (2009); Barros et al. (2010); Yu (2010); Assaf (2011); Fung and Chow (2011); Lozano and Gutiterrez (2011); Tsekeris (2011); Assaf and Gillen (2012); Chow and Fung (2012); Perelman and Serebrisky (2012); Scotti et al. (2012); Wanke (2012b).	25
Number of runways	Gillen and Lall (1997; 2001); Sarkis (2000); Bazargan and Vasigh (2003); Pels et al. (2003); Oum et al. (2003; 2008); Sarkis and Talluri (2004); Lin and Hong (2006); Barros (2008a); Pathomsiri et al. (2008); Assaf (2010); Yang (2010); Curi et al. (2011); Tsekeris (2011); Wanke (2012b).	16
Number of gates	Gillen and Lall (1997; 2001); Sarkis (2000); Bazargan and Vasigh (2003); Oum et al. (2003); Sarkis and Talluri (2004); Lin and Hong (2006); Tovar and Martin-Cejas (2010); Lozano and Gutiterrez (2011).	9
Size of apron	Fernandes and Pacheco (2002); Pacheco and Fernandes (2003); Yu (2004); Barros (2008a); Yu (2010); Curi et al. (2011); Lozano and Gutiterrez (2011); Tsekeris (2011); Wanke (2012b).	9
Number of check-in desks	Pels et al. (2001; 2003); Fernandes and Pacheco (2002); Pacheco and Fernandes (2003); Lin and Hong (2006); Lozano and Gutiterrez (2011); Scotti et al. (2012).	7
Length of runway	Gillen and Lall (1997); Abbott and Wu (2002); Yoshida and Fujimoto (2004); Fung et al. (2008); Chi-Lok and Zhang (2009); Fung, Chow (2011); Chow and Fung (2012); Wanke (2012b).	7
Number of parking spots	Gillen and Lall (1997; 2001); Fernandes and Pacheco (2002); Pacheco and Fernandes (2003); Lin and Hong (2006); Wanke (2012b).	6
Number of collection belts	Gillen and Lall (1997; 2001); Pels et al. (2001); Lin and Hong (2006); Lozano and Gutiterrez (2011); Scotti et al. (2012).	6
Number of aprons	Pels et al. (2001; 2003); Lin and Hong (2006); Scotti et al. (2012); Wanke (2012b).	5
Financial Variables		
Operational cost	Sarkis (2000); Bazargan and Vasigh (2003); Sarkis and Talluri (2004); Vashigh and Gorjidooz (2006); Barros and Dieke (2007; 2008); Barros (2008b); Barros (2009); Curi et al. (2010); Yang (2010); Assaf (2011); Barros (2011); Assaf and Gillen (2012); Gitto and Mancuso (2012b).	14
Capital cost	Hooper and Hensher (1997); Parker (1999); Martin and Roman (2001; 2006); Barros and Sampaio (2004); Barros and Dieke (2007; 2008); Martin et al. (2009); Curi et al. (2010); Assaf et al. (2012).	10
Labour cost	Hooper and Hensher (1997); Martin and Roman (2001; 2006); Barros and Dieke (2007; 2008); Oum et al. (2008); Curi et al. (2010); Assaf et al. (2012); Gitto and Mancuso (2012b).	9
Amount of capital stock	Murillo-Melchor (1999); Parker (1999); Abbott and Wu (2002); Yu et al. (2008).	4

Source: Organised by author.

2.3.4.2 OUTPUT VARIABLES ANALYSIS

The output variables (see Table 2.4) used in airport performance research can again be divided into airport service variables (such as number of passengers, amount of cargo, and number of aircraft movement) and financial variables (such as operational revenue, non-operational revenue, aeronautical revenue, and non-aeronautical revenue). However, despite the importance of such variables for airport managers, the number of studies using financial outputs is relatively limited, even where financial inputs are used (Humphreys and Francis 2002b).

Among output variables, the number of passengers was the most broadly adopted variable to evaluate airport efficiency. In addition, the amount of cargo, mail and aircraft movement were also considered by many studies to be essential in airport activities. Among financial variables, non-aeronautical revenue was the most broadly used financial variables. Oum et al. (2003) revealed that, in addition to passenger traffic, cargo traffic and aircraft movements, airports also derive revenues from concessions, car parking, and numerous other services. These 'other' services are not directly related to aeronautical activities in a traditional sense, but they are becoming increasingly more important for airports around the world. Consequently, when considering output variables, that of revenues from commercial or non-aeronautical services should be included.

Most studies only applied three output variables, a notable exception being the study of Barros and Dieke (2007), which used both service and financial variables. Considering other outputs of airports, variables such as punctuality were only included in one paper (i.e. Bazargan and Vasigh 2003) even though there were many external influences on this variable. More interestingly, with topics related to sustainability now becoming increasingly important, environmental outputs only have been studied in a few papers, such as research by Yu (2004), who considered aircraft noise as an output. In addition, Graham (2004) suggested the use of several variables when evaluating airport environmental performance (such as waste per passenger and water consumption per passenger). These environmental variables offer significant potential scope for future research.

Table 2.4: The most popular output variables

Input Variables	Papers	
Airport Service Variables		
Number of passengers	Gillen and Lall (1997; 2001); Murillo-Melchor (1999); Parker (1999); Sarkis (2000); Martin and Roman (2001); Pels et al. (2001; 2003); Abbott and Wu (2002); Fernandes and Pacheco (2002); Pacheco and Fernandes (2003); Oum et al. (2003; 2006; 2008); Barros and Sampaio (2004); Oum and Yu (2004); Sarkis and Talluri (2004); Yoshida (2004); Yoshida and Fujimoto (2004); Yu (2004); Lin and Hong (2006); Martin and Roman (2006); Vashigh and Gorjidooz (2006); Barros and Dieke (2007; 2008); Barros (2008a; 2008b; 2009); Fung et al. (2008); Pathomsiri et al. (2008); Yu et al. (2008); Chi-Lok and Zhang (2009); Lam et al. (2009); Assaf (2010); Ablanedo- Rosas and Gemoets (2010); Curi et al. (2010); Yu (2010); Assaf (2011); Barros (2011); Curi et al. (2011); Fung, Chow (2011); Lozano and Gutiterrez (2011); Tsekeris (2011); Assaf and Gillen (2012); Chow and Fung (2012); Gitto and Mancuso (2012b); Perelman and Serebrisky (2012); Scotti et al. (2012); Wanke (2012a); Wanke (2012b); Zhang et al. (2012).	50
Aircraft movements	Sarkis (2000); Martin and Roman (2001); Pels et al. (2001; 2003); Oum et al. (2003; 2006; 2008); Oum and Yu (2004); Barros and Sampaio (2004); Sarkis and Talluri (2004); Yoshida (2004); Yoshida and Fujimoto (2004); Yu (2004); Lin and Hong (2006); Martin and Roman (2006); Vashigh and Gorjidooz (2006); Barros (2008a; 2008b; 2009); Barros and Dieke (2008); Fung et al. (2008); Chi-Lok and Zhang (2009); Lam et al. (2009); Martin et al. (2009); Assaf (2010); Ablanedo- Rosas and Gemoets (2010); Curi et al. (2010); Yu (2010); Assaf (2011); Barros (2011); Fung, Chow (2011); Curi et al. (2011); Lozano and Gutiterrez (2011); Tsekeris (2011); Assaf and Gillen (2012); Chow and Fung (2012); Gitto and Mancuso (2012b); Perelman and Serebrisky (2012); Scotti et al. (2012); Wanke (2012b); Zhang et al. (2012).	43
Amount of cargo and mail	Gillen and Lall (1997; 2001); Parker (1999); Sarkis (2000); Martin and Roman (2001); Abbott and Wu (2002); Oum et al. (2003; 2008); Barros and Sampaio (2004); Sarkis and Talluri (2004); Wang et al. (2004); Yoshida (2004); Yoshida and Fujimoto (2004); Lin and Hong (2006); Martin and Roman (2006); Barros and Dieke (2007, 2008); Barros (2008a); Fung et al. (2008); Pathomsiri et al. (2008); Chi-Lok and Zhang (2009); Lam et al. (2009); Ablanedo- Rosas and Gemoets (2010); Assaf (2010); Curi et al. (2010); Yu (2010); Assaf (2011); Curi et al. (2011); Fung, Chow (2011); Lozano and Gutiterrez (2011); Tsekeris (2011); Chow and Fung (2012); Gitto and Mancuso (2012b); Perelman and Serebrisky (2012); Scotti et al. (2012); Wanke (2012a); Wanke (2012b); Zhang et al. (2012).	39
Financial Variables		
Amount of non-aeronautical revenue	Hooper and Hensher (1997); Bazargan and Vasigh (2003); Oum et al. (2003; 2006; 2008); Oum and Yu (2004); Barros and Sampaio (2004); Martin and Roman (2006); Barros and Dieke (2007; 2008); Curi et al. (2010); Tovar and Martin-Cejas (2010); Assaf and Gillen (2012); Assaf et al. (2012); Gitto and Mancuso (2012a); Gitto and Mancuso (2012b).	16
Amount of aeronautical revenue	Hooper and Hensher (1997); Bazargan and Vasigh (2003); Barros and Sampaio (2004); Martin and Roman (2006); Barros and Dieke (2007; 2008) Curi et al. (2010); Assaf et al. (2012); Gitto and Mancuso (2012a); Gitto and Mancuso (2012b).	10
Amount of operational revenue	Sarkis (2000); Sarkis and Talluri (2004); Vashigh and Gorjidooz (2006); Yang (2010).	4
Amount of non-operational revenue	Vashigh and Gorjidooz (2006).	1

Source: Organised by author.

2.4 ANALYSIS OF RESEARCH SAMPLE

Regarding comparing the results arising from the research, it should be noted that efficiency is a relative concept: the efficiency of a DMU is measured in relation to the frontier that, in turn, is defined by a group of DMUs. This means that any change in the group of DMUs analysed, such as the inclusion or exclusion of an airport, will change the calculated efficiency indexes. In general terms, people indicate that the performance of airports has improved over time since most studies have found evidence of improvements in efficiency, productivity, or in regard to the introduction of new technology. A review of the previous studies have shown that many different variables affect airport efficiency, including airport characteristics, hub status and traffic structure (Gillen and Lall 1997; Oum et al. 2006; Oum et al. 2006; Tovar and Martin-Cejas 2010). In terms of managerial control, commercialisation, privatisation, and outsourcing policy also influence airport performance (Oum et al. 2003; Barros and Dieke 2008; Vasigh and Gorjidooz 2006). However, airports in different countries are affected by different variables. Therefore, the following sections discuss papers that have a single country research focus and those which cover multiple countries (reflecting the data in Figure 2.1).

2.4.1 SINGLE COUNTRY RESEARCH

This section focuses upon those countries where there have been at least four different studies into airport efficiency, which include the USA, UK, Spain, and Taiwan. Details of these studies can be found in Table 2.5. In general terms, most of these studies showed an improvement in airport efficiency over time, with only Gillen and Lall (2001) claiming that there was a 0.1% decline in the terminal side and movement side. A key feature of many of these single country studies was the comparison of airports by size. The typical classification that is used is small, medium and large. In the US, early studies were conducted by Gillen and Lall (1997) and Sarkis (2000), who both used data covering a period from 1989 to 1994. They both found that larger airports are more efficient than small airports. More recent studies covering the period from 1996 to 2003, showed that smaller US airports have became more efficient than large airports (Bazargan and Vasigh 2003; Pathomsiri et al. 2008). This finding suggests that there are changing dynamics within the airport system in the US.

Similar trends can be seen in studies of airports in the UK and Taiwan. In the UK, large airports have gone from being less efficient (Barros 2008b; 2009) to being more efficient (Assaf 2009). Meanwhile, in Taiwan, small airports were originally found to be more efficient (Yu 2004), but by 2001, the efficiency levels were similar for all airport sizes (Wang et al. 2004). Only Spain has exhibited a consistent trend. Spain's larger airports continued to be the most efficient airport size throughout the period studied. However, all of these studies used data sets from similar years.

2.4.2 CROSS COUNTRY RESEARCH

This section addresses those studies in airport efficiency that were conducted in multiple countries. Details of these studies can be found in Table 2.6. One of the key features in these studies of airport efficiency was ownership structure. Like other studies on the empirical evidence of ownership, the question of whether privatisation increases the efficiency of airports was still inconclusive in these studies. Pels et al. (2001) separated airport operation into landside and airside operations and developed separate DEA models to evaluate their productive efficiency. Their results indicated that most private airports achieve higher levels of efficiency as compared to their non-privatised counterparts. More recently, Vasigh and Gorjidooz (2006) measured the effects of ownership on airport TFP for a sample of 24 airports from the UK (seven of which were private), other European countries (seven public-private) and the US (eight public). The results revealed that there was no significant relationship between financial and operational efficiencies. The same result was achieved by Lin and Hong (2006), who used DEA to assess airport operating efficiency.

The various studies published by Oum, T. H. also portrayed a varied response to the question of ownership, suggesting a potential evolution over time. For example, the results of Oum et al. (2003) and Oum and Yu (2004), using data from 1999 to 2001, concluded that ownership had no statistically significant impact on productivity. However, in studies that were published in 2006 and 2008, the results showed that majority ownership by the private sector brings about higher efficiency as compared to public sector ownership (Oum et al. 2006; 2008).

Table 2.5: Single country research

Studies	Sample	Findings
US		
Gillen and Lall (1997)	21 US airports (1989~1993)	Terminal efficiency in 11 airports improved while movement efficiency in 12 airports improved. Large airports are more efficient than small and medium airports.
Sarkis (2000)	44 US airports (1990~1994)	The sample saw a 5.5% improvement in average efficiency. Large airports are more efficient than small and medium airports.
Gillen and Lall (2001)	22 US airports (1989~1993)	TFP growth of -0.1% per year in the terminal side. TFP growth of -0.1% per year in the movement side.
Bazargan and Vasigh (2003)	45 US airports (1996~2000)	Efficiency for large and medium hub airports is not statistically different. Overall, small airports are more efficient than large airports.
Sarkis and Talluri (2004)	44 US airports (1990~1994)	Among 44 airports, average efficiency increased from 0.681 to 0.737.
Pathomsiri et al. (2008)	56 US airports (2000~2003)	The number of efficient airports increased from 4 to 28. Overall, small airports are more efficient than medium and large airports.
Spain		
Murillo-Melchor (1999)	33 Spanish airports (1992~1994)	Average efficiency was 0.6141, with little difference over the time period analysed.
Martin and Roman (2001)	37 Spanish airports (1997)	With constant returns to scale, average efficiency was 0.6, and 8 airports are relatively efficient. With variable returns to scale, average efficiency was 0.7, and 13 airports are relatively efficient. Large airports such as Madrid and Barcelona are more efficient than others.
Martin-Cejas (2002)	40 Spanish airports (1996~1997)	Small and large airports achieve higher efficiency.
Martin and Roman (2006)	34 Spanish airports (1997)	Large airports achieve higher efficiency.
Martin et al. (2009)	37 Spanish airports (1991~1997)	The larger airports are more efficient.
Tovar et al. (2010)	26 Spanish airports (1993~1999)	TFP growth at 0.9% per year. Offshore airports above average efficiency.
Lozano and Gutierrez (2011)	41 Spanish airports (2006)	Half of the airports were found to be technically efficient.
UK		
Parker (1999)	32 UK airports (1979/80~1995/96)	Efficiency before privatisation was 0.988, after privatisation was 0.931.
Barros (2008b)	27 UK airports (2000/01~2004/05)	The most efficient airport is Luton and the largest airports (i.e. Heathrow, Gatwick, and Manchester) are the weakest.
Barros (2009)	27 UK airports (2000~2006)	Luton airport is the most efficient airport, and Heathrow is the least efficient.
Assaf (2009)	27 UK airports (2007)	Large airports are more efficient than small airports.
Taiwan		
Wang et al. (2004)	10 Taiwan Airports (2001)	Among three different size airports, the efficiency is almost the same. (Large: 0.461, Medium: 0.457, and Small: 0.461).
Yu (2004)	14 Taiwan Airports (1994~2000)	Small airports can achieve a higher level of efficiency as compared to large airports.
Yu et al. (2008)	4 Taiwan airports (1995~1999)	Airport efficiency is increasing yearly.
Yu (2010)	15 Taiwan airports (2006)	Offshore airports are more efficient than mainland airports.

Source: Organised by author.

Note: The study by Hamazee and Vasigh (2000) is not included for the US because they established a revenue and cost model for current US airport authorities but did not apply it to empirical data.

Table 2.6: Cross country research

Studies	Sample	Findings
Pels et al. (2001)	34 European airports (1995~1997)	Most private airports achieve higher efficiency than public airports.
Oum et al. (2003)	50 airports around the world (1999)	Larger airports achieve higher gross TFP because of the economies of scale in airport operations. An airport's ownership structure does not appear to have any statistically significant effect on its productivity performance.
Oum and Yu (2004)	76 airports around the world (2001-2002)	Larger airports are more efficient due to economies of scale. There is no statistical significance in the difference between different ownership structures.
Lin and Hong (2006)	20 airports around the world (2003)	The form of ownership and the size of an airport are not apparently correlated with operational performance of airports. In contrast, the existence of a hub airport, the location of the airport, and the economic growth rate of the country in which the airport is located are all related to the operational performance of airports.
Oum et al. (2006)	116 airports around the world (2003~2005)	Airports with government majority ownership and those owned by multi-levels of government are significantly less efficient than airports with a private majority ownership.
Vashigh and Gorjidooz (2006)	22 US and European airports (2000~2004)	In every year, the performance of airports in the US was better than airports in the UK and EU, but there was no obvious difference in terms of ownership.
Oum et al. (2008)	109 airports around the world (2007)	100% privately owned airports perform better than public airports. Privatisation of one or more airports in cities with multiple airports would improve the efficiency of all airports.
Lam et al. (2009)	11 airports in Asia Pacific (2001-2005)	Technical, scale and mix efficiencies are high among the major Asia Pacific airports. Between these eleven airports, Brisbane achieves relative efficiency in every year under consideration.
Yang (2010)	12 airports in Asia Pacific (1998~2006)	Airports should focus more on investment than on human resources. In addition, the inefficiency effects associated with the production functions of airports increased over the investigated period.

Source: Organised by author.

2.5 SUMMARY

This chapter examined the current studies on airport efficiency. After reviewing the majority of published airport benchmarking studies, this literature survey showed that the analysis of performance evaluation in the airport sector has enjoyed significant contributions in recent years. For the period under consideration, airport research has shown a growth in terms of the number of research areas, and a number of analysis techniques from other disciplines have been used to meet the research demand, derived from the complex phenomena taking place in the airport industry. It is also characterised by a number of dominating features, including a focus on publication in two journals and a focus on airports in the most important regions for air transport.

The potential analysis techniques which can be used in the research are also widely described. A few important methodological points emerge suggesting that the DEA approach has been the methodology that has been traditionally used to reflect the multi-production nature of the airport sector, although SFA and TFP have also seen limited use.

A wide variety of input variables have been used with regard to the measurement of labour, capital and the inclusion of material and outsourcing. Meanwhile, a number of studies have only used the output variable of aeronautical activities although the commercial side has recently received more attention. Other studies have combined the output variables of passengers and cargo to movement as a single measure, effectively treating them equally. From this analysis, a principle of variables selection for this research has been confirmed.

A structure of research themes used in airport research has been constructed in this literature review, and theoretical bases and disciplinary characteristics have been identified. This chapter has defined the positioning of this thesis in airport research with regard to these features of airport research. The further concepts of this thesis are described in the next chapter.

CHAPTER 3

DEVOLUTION OF AIRPORT OWNERSHIP AND GOVERNANCE

The aims of reviewing the changing nature of airports in this chapter are to understand the nature of airport ownership and governance, to illustrate the evolution of airport ownership and governance, and to justify the differences existing between diverse areas. To achieve these aims, first how an airport is constructed is described. Then an investigation is conducted into the periodic changes that have occurred in airport ownership in order to enable an understanding of the current positioning of this period in the periodic timeline.

3.1 AIRPORT OWNERSHIP AND GOVERNANCE

From previous experience with the UK and US, the periodicity of airport ownership and governance evolution can be illustrated in three periods: governmental control, corporatisation and commercialisation, and privatisation.

3.1.1 THE PERIOD OF GOVERNMENTAL CONTROL

In this period, airport ownership patterns evolved unevenly over time and space for a variety of reasons. A similar evolution is revealed when reviewing the formation of airports in the US and UK. During World War II, the governments of these two countries spent significant resources to repair and construct airports for military service. In 1947, the UK government transferred the ownership and management of 44 airports to the Ministry of Civil Aviation (Humphreys 1999). In addition, in the US, more than 500 airports were declared to be military surplus and were subsequently handed over to the authorities of cities, counties, and states for strictly civilian aviation use (Wells and Young 2004). During this time, all airports were typically owned by the public sector and used by political bodies as a fundamental tool in the practice of establishing and reinforcing their citizens' consensus (Jarach 2005). Graham (2008) found that during this period, airport ownership could be categorised into three main patterns.

(1) Owned and operated by a national government

These airports served major cities (such as Tokyo, Bangkok, Paris, London, and Singapore) and were usually operated by national governments.

(2) Owned and operated by local governments

These were regional airports that were usually operated by local governments (at a regional or municipal level). Most of the airports in the US and some regional airports in the UK followed this pattern.

(3) Owned and operated by a multi-level public sector

A number of airports were controlled by both the local and national government. For example, Munich airport, which was founded in 1949, was owned by three shareholders: the Free State of Bavaria (51%), the Federal Republic of Germany (26%) and the City of Munich (23%) (Wragg 2009).

3.1.2 THE PERIOD OF CORPORATISATION AND COMMERCIALISATION

Between the 1970s and 1980s, the first steps towards airline privatisation and deregulation took place as the air transport industry grew and matured, and at the same time the philosophies of airport management began to change (Graham 2008). In this period, a trend labelled corporatisation and commercialisation was developed and introduced by several acts of the US Congress that related to the air transport industry at this time[1]. After those Acts were implemented, the passage of the American Air Cargo Deregulation Act of 1976 and the Airline Deregulation Act of 1978 implied that the US air transport industry was growing and maturing. However, U.S. domestic deregulation spilled over into international air transport (Doganis 2002). In Europe, there were similar winds of change, such as in the UK, where the civil aviation authority became increasingly liberal in its licensing decisions from 1975 onwards (Doganis 2002). Consequently, many airports gradually started to be considered much more as commercial enterprises, and a more businesslike management philosophy was adopted. Therefore, commercialisation of the airport industry had started to take place. However, most countries at this time had some sort of restrictions on public-sector engagement in commercial activities. Therefore, before moving towards commercialisation, airport corporatisation first took place.

There are many different interpretations of what exactly is meant by the terms corporatisation and commercialisation. Generally, corporatisation is defined as an attempt to introduce the rigours and philosophies of private industry while the government retains control and ownership (Graham 2011). Meanwhile, airport corporatisation may be defined as the establishment of a legal and independent airport company wholly owned and controlled by the government or local authorities (Shearman 1992; Graham 2008). Airport commercialisation can be defined as the transformation of an airport from a public utility to a commercial enterprise with the adoption of more business-like management philosophies, values, and approaches while the airport remains publicly owned (Humphreys 2002a). The drivers of commercialisation are determinant on the need for investment expertise and resources that are not available or accessible to the public sector. Moves toward

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[1] The Department of Transportation (DOT) was established in 1967; in 1970, the Airport and Airway Development Act and the Airport and Airway Revenue Act were signed; in 1976, the Airport and Airway Development Act Amendments was implemented

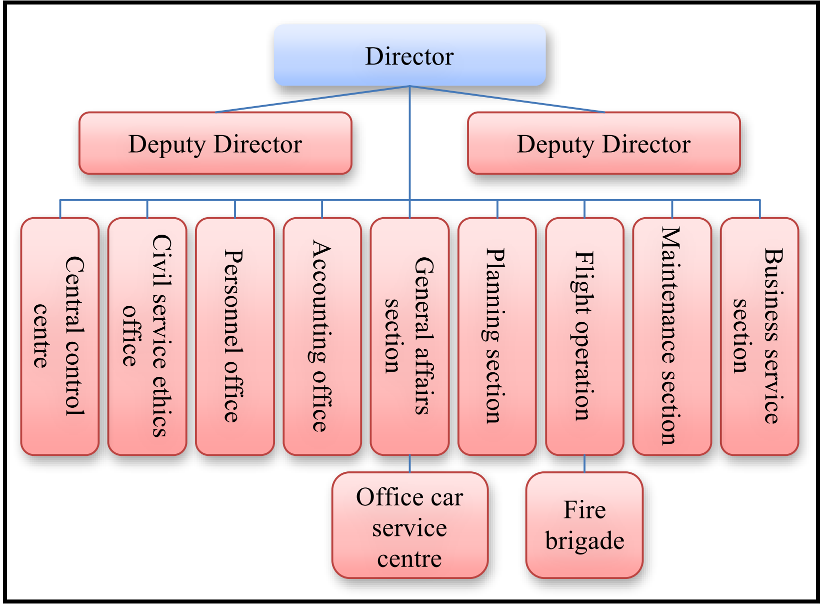
commercialisation can be recognised through a number of different inter-related developments. Firstly, a number of airports achieved a degree of autonomy by establishing more independent airport authorities with public sector shareholding. Secondly, many airports moved towards becoming profit-orientated self-financing entities by addressing non-aeronautical activities, such as retail and concession management. Commercialisation indicates a greater emphasis on financial rather than operational issues. Thirdly, airport commercialisation is typified by an improvement in customer focus with improvements to airline facilities, commercial areas, and landside amenities and infrastructure (Doganis 1992; Graham 2008; Starkie 2008). The most significant changes of how airports were operated in this period are described in the following points:

(1) Management organisation structure

Traditionally, airport management structures have reflected a functional approach in regard to dividing up responsibilities and lines of authority (Jarach 2005). They also provide a framework within which management functions can be carried out. Usually, these include operations, administration, engineering, finance and personnel or safety. An example of this type of organisation drawn from an Asian airport is shown in Figure 3.1, which shows the formal airport authority relationship between superiors and subordinates at various levels, as well as the formal channels of communication within the organisation in the past.

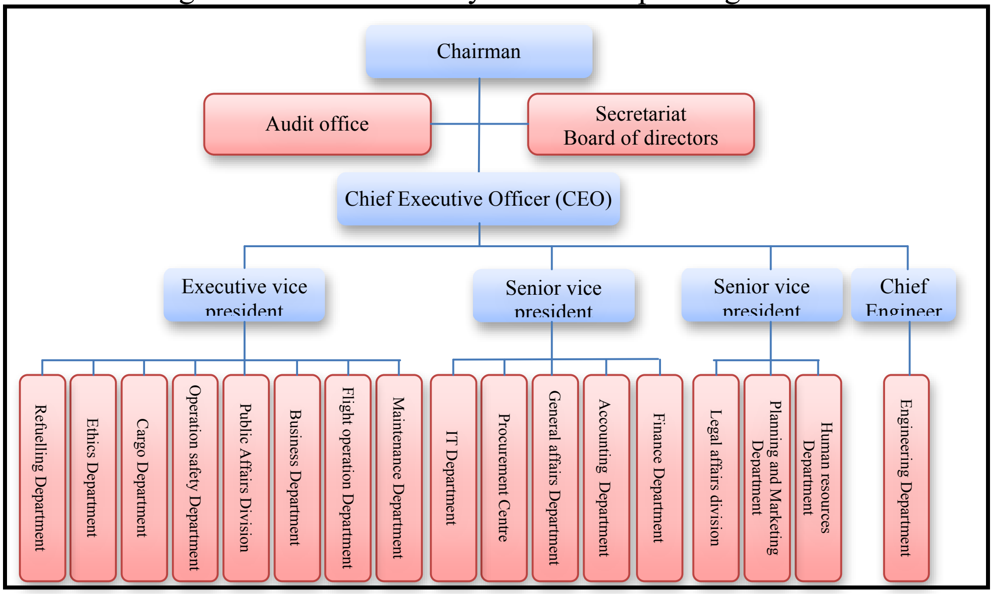
After corporatisation, in order to increase non-aeronautical revenue, an airport must be organised in such a way that commercial activities are given the importance they deserve, which includes the need to be a clearly identified focus of responsibility for commercial activities. The airport must be organised into different business areas with a senior manager responsible for each, rather than being organised along functional divisions. An airport following the commercial airport model is a business as well as a provider of services. Each of the businesses then either retains the functional skills which they require within their own department or draws upon skills as necessary from separate service departments or from outside the airport organisation. An example of modern airport organisation is shown in Figure 3.2.

Figure 3.1: Traditional airport organisation



Source: Wensveen (2007).

Figure 3.2: Commercially oriented airport organisation



Source: Wensveen (2007).

Airport organisations have become more and more specific, and airports are now operated in a dynamic environment and as entities that continually adapt to changing conditions. Consequently, some old positions might no longer be required, or they may be merged with other departments while some new positions, such as the public affairs division, might have to be created in order that new objectives can be reached (Wragg 2009). After corporatisation, airport organisations structures can be revised and updated periodically more easily and are more flexible with regard to reflecting these changing conditions. In some airports, the typical functional organisational structure with different departments for finance, operations, administration, and so on, was replaced with departments or business units that were more focused on their customers' needs (such as airline or passenger services) because the commercial functions of the airports were gradually recognised as being equally important. Therefore, the resources and staff numbers employed in these areas were expanded. In addition, the benchmarking of financial performance and quality management techniques also began to be accepted by a growing number of airports as essential management tools in this period (Humphreys 1999).

(2) Revenue generation

Airport revenue is usually classified into two main categories: aeronautical and non-aeronautical revenues. Aeronautical revenues are those sources of income which arise directly from the operation of aircraft and the processing of passengers and freight. Non-aeronautical revenues are those generated by activities that are not directly related to the operation of aircraft, notably income from commercial activities within the terminal and rents for terminal space and airport land (Graham 2008). The International Civil Aviation Organisation (ICAO) has a long list of activities that can be classified as non-aeronautical revenue or aeronautical revenue (see Table 3.1).

Table 3.1: Activities of non-aeronautical revenue and aeronautical revenue

Aeronautical Revenues	Non-Aeronautical Revenues
➢ Landing charges (including lighting and approaching, and aerodrome control charges) ➢ Passenger service charges ➢ Cargo charges ➢ Parking and hangar charges ➢ Security charges ➢ Noise-related charges ➢ Other charges on air traffic operations ➢ Ground-handling charges[2]	➢ Aviation fuel and oil concessions (including throughput charges) ➢ Restaurants, bars, cafeterias and catering services ➢ Duty-free shops ➢ Automobile parking ➢ Other concession and commercial activities operated by the airport. ➢ Rentals ➢ Other revenues from non- Aeronautical activities

Source: ICAO (2006).

The evidence to show that airport authorities put emphasis on revenue generation can be found in Chapter 2. From Table 2.4, for the purpose of evaluating airport efficiency,

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[2] Some airports have already outsourced ground-handling service, and at the majority of airports, this service is largely carried out by one or more airlines or special ground-handling enterprises. In some cases, the airport will impose concession and/or rental fees which are recorded as revenues from non-aeronautical activities.

the amount of both aeronautical revenue and non-aeronautical revenue were adopted by 26 different papers, and most of them were published after the year 2000. Another significant characteristic of the trend towards commercialisation and an increased focus on treating airports as businesses was greater reliance being placed on non-aeronautical or commercial revenues (Graham 2006). Aeronautical revenues, such as landing and passenger fees from the airlines, had traditionally been the most important source. In 1970s, aircraft landing fees represented by far the most significant part of aeronautical revenues from passenger-related charges (Doganis 1992). For a number of airports, especially in Europe, non-aeronautical sources overtook aeronautical sources as being the most important source of revenue.

A breakdown of revenues for a sample of European airports is shown in Table 3.2 for the period between 1983 and 2009. The main watershed in this table happened in 1998/99 with the rise in the importance of aeronautical revenues concurrent with a subsequent increase in reliance on non-aeronautical sources. This reflects not only pressure from airlines and regulatory bodies to keep airport charge increases to a minimum, but it also reflects the increased focus being placed on commercial activities. This development was primarily the result of greater space being allocated to retail and other non-aeronautical facilities, the quality being improved and the range of commercial activities being expanded. Not only in the Europe, according to the statistics which were published by Airport Council International (ACI) in 2011, in 2010, non-aeronautical revenue also became the majority of total revenue in some other regions such as Africa/the Middle East (55%), Asia/Pacific (52%), and North America (55%).

Table 3.2: Average revenue and cost structures at European airports

	1983 /84	1988 /89	1993 /94	**1998 /99**	2003 /04	2006 /07	2007 /08	2008 /09
Revenues shares (%)								
Aeronautical	59	56	54	**50**	51	52	49	48
Non-Aeronautical	41	44	46	**50**	49	48	51	52
Total	100	100	100	**100**	100	100	100	100

Source: Graham (2008); ATRS annual report (2010).

(3) Airport marketing

The airport industry historically had played a passive role towards marketing, and it responded to customer needs only when necessary (Jarach 2005). Because of commercialisation and the deregulation of the airline industry, the competition between airports has gradually increased over the last three decades. Airport competition can be considered on two different levels: competition between airport groups and competition within airport groups. In some major urban areas or cities, there are a number of situations when more than one airport serves the population. Notable examples are the European cities of London and Paris, and the Asian cities of Tokyo and Shanghai. In many cases when there are overlapping areas, one airport tends to become the dominant player in a preferred location with the other airports playing a more secondary role. However, when airports are operated as a system, such as Tokyo Narita and Haneda airport, or as a group, such as London Heathrow and Gatwick airport, which were also supported by Luton and Standsted before 2009, there is an important issue as to whether this inhibits competition (Forsyth 2006).

However, in such a turbulent environment, the development and management of a supplier and customer relationship is of primary strategic importance. A more businesslike approach to airport management should be coupled with a more commercially driven and competitive airline industry. This encourages airports to take more active and positive roles. Modern airports have to undertake this kind of recruitment because the modern airline industry, which has been transformed in many places from a regulated and public sector controlled activity into a liberalised and commercially orientated business, has played a major role in this changing airport situation (Graham 2008). In addition, some airline developments (such as the formation of global alliances) have been particularly important, as has been the development of the low-cost sector, with regard to creating new views on airport competition. Airport competition is a complex area to examine because there are different aspects which can be considered (Graham 2006). In order to cope with this, another important issue is the role of marketing. In the UK, for example, most of the airports during this corporatisation and commercialisation period developed marketing departments which started to use pricing tactics and promotional campaigns to attract new customers (airline or retail companies) and which began to undertake market research (Humphreys

1999). In other countries, this phenomenon also occurred in those airports which had been corporatised.

3.1.3 THE PERIOD OF PRIVATISATION

The literature on agency theory and strategic management suggest that ownership influences a firm's performance because different owners pursue different goals and have different incentives (Vickers and Yarrow 1998; Oum et al. 2006). Under government ownership and management, a firm is operated by bureaucrats whose objective function is a weighted average of social welfare and their own personal agendas. Under private ownership, by contrast, the firm maximises profit (i.e. the shareholders' value) (Cullinane et al. 2011). A recent common-sense view is that government-owned firms are less efficient than their private sector counterparts operating in similar situations. Consequently, the effects of ownership on a firm's productive efficiency have been an important topic of research. The 1990s were a decade when airport privatisation in western countries became a reality. Privatisation of an airport may be defined simply as the whole or part moves from public to private ownership, with substantial involvement of private sector management and operation (Humphreys 1999). Another common-sense view suggests that privatisation reduces the need for public sector investment and that free access to commercial markets will bring improved efficiency, greater competition and a wider share of ownership (Graham 2009).

A number of reasons why these governments sought to devolve responsibility for airport ownership at this time are as follows: (Parker 1999; Humphreys and Francis 2002a; Graham 2005; Oum et al. 2008).

(1) It reduces dependency on government resources.
(2) Airport expansion increases catchments and influence.
(3) A publicly owned airport is unable to attract finances or to attract market investment.
(4) It focuses on customer requirements.
(5) It focuses on policy and regulations.

According to Oum et al. (2006) and Gillen (2011), ownership and governance form can be classified into eight different categories, which are as follows:

(1) Government owned and operated (e.g. Finland, and some airports in the US).

(2) Mixed private–government ownership, with the private sector owning a majority share (e.g. Denmark, Austria, and Switzerland).
(3) Mixed government–private ownership, with the government owning a majority share (e.g. Hamburg, France, China, and Kansai-Japan).
(4) Government ownership but contracted out to an airport authority under a long term lease (e.g. Chile, Hamilton and some airports in the US).
(5) Multi-level governments who form an authority to own and operate airports in the region (e.g. some airports in the UK).
(6) 100% government corporation ownership and operation (e.g. Singapore, Hong Kong, and Taiwan).
(7) Fully private ownership (e.g. BAA).
(8) Independent non-profit corporations (e.g. Canada).

This research, in order to include the all possibilities, the sample airports, which are selected in this research, should try to cover these eight types of airport ownership. In addition, privatisation does come along with some hazards. The theoretical arguments for and against privatisation of publicly owned organisations, particularly when a share flotation is being considered, are well known. For example, it may create a private monopoly which overcharges, may deliver poor standards of service, may invest inadequately and may give insufficient consideration to externalities and other disadvantages (Beesley 1997). This may also happen in the airport industry. Therefore, when privatising airports, the government usually set up several regulations or regulatory bodies to manage private airports.

3.2. AIRPORT OWNERSHIP EVOLUTION IN DIFFERENT AREAS

The evolution of airport ownership in North America, Europe, and Asia has been experienced in different periods of time. In order to understand the differences in the main countries on different continents, the airport ownership evolution of The US, which was the first country to implement airport commercialisation, the UK, which was the first country to undertake fully airport privatisation policy, and China, which will be the most important country in the air transport industry in the next 20 years, are described in the following subsections.

3.2.1. NORTH AMERICA: THE UNITED STATES OF AMERICA

In general, airports in the US are almost the most privatised in the world, despite the fact that all of the major commercial airports are owned by government entities. Compared to airports elsewhere in the world and even to the airports in the countries that have recently privatised their airports, the major US airports have experienced an extensive degree of private control over virtually every aspect of airport planning, design, finance, operations, pricing and access, but not ownership (Neufville 1999).

The high level of private participation in the management and strategic development of major commercial airports in the US is summarised in Table 3.3. While the degree of involvement of private companies in the control of airports varies widely from state to state and from city to city, the overall situation is that major American commercial airports are run through a form of partnership between the federal government, local civic interests, and private companies.

Table 3.3: Level of privatisation for major commercial US airports

Elements of Control	Typical Status	Details
Planning for expansion	Government/Private	Government leads, but private interests influence the decision through their willingness to provide financing or to accept plans under majority-in-interest clauses in leases.
Design of projects	Largely Private	Airlines and users have significant, often decisive, control over design. Private consultants typically execute designs.
Financing	Largely Private	Mix of public (mostly federal) and private sources, with a significant fraction of money coming from bonds issued in capital markets.
Operation of facilities	Largely Private	Operation of facilities largely done by airlines and other third parties.
Pricing of services	Government/Private	Price is set in negotiation with major users and is subject to legal controls on increases.
Availability of services	Government/Private	Principle of open access to all qualified users generally holds, subject to airlines and other third parties controlling the use of their facilities.
Ownership of properties	Government	Municipal or regional agencies.

Source: Neufville (1999).

Public airports in the US are owned and operated under a variety of organisational and jurisdictional arrangements. Commercial airports might be owned and operated by a city, county, or state; by the federal government or may be owned by more than one jurisdiction (e.g. a city and a county). In some cases, a commercial airport is owned by one or more of these governmental entities but operated by a separate public body, such as an airport authority that is specifically created for the purpose of managing the airport. Regardless of ownership, the legal responsibility for the airport's day-to-day operation and administration can be vested in any of five kinds of governmental or public entities, which include a municipal or county government, a multipurpose port authority, an airport authority, a state government, or the federal government (Wells and Young 2004).

In the US, airport privatisation typically involves the lease of airport property and/or facilities to a private company to build, operate, and/or manage commercial services offered at the airport. However, no commercial airport property has been completely sold to a private entity. From a service perspective, although no US commercial airport has been sold to a private entity, many publicly-owned airports have extensive private sector involvement. Most of the services that are now performed at large commercial airports (such as airline ticketing, baggage handling, cleaning, retail concessions, and ground transportation) are provided by private firms (Wragg 2009). Some estimates indicate that as many as 90% of the people working at the nation's largest airports are employed by private firms. The remaining 10% of the employees include local and state government personnel performing administrative or public safety duties, federal employees, such as Federal Aviation Administration (FAA) air traffic controllers and Transportation Security Agency (TSA) security screeners, or other public employees, which are made up primarily of military personnel (FAA 2011). From a financial perspective, many airports in the US are now relying more on private financing for capital development. Airports have sought to diversify their sources of capital development funding, including the amount of private sector financing. Several reasons have motivated this interest in expanding the role of the private sector at commercial airports in the US (Wells and Young 2004). Firstly, privatisation advocates believe that private firms will provide additional capital for development. Secondly, proponents believe that privatised airports will be more profitable because the private sector will operate them more efficiently. Lastly, advocates believe that privatisation will financially benefit all levels of government by reducing demand on public funds and by increasing the tax base.

Since 1997, the FAA has implemented the Pilot Programme on Private Ownership of Airports. Under this programme, five public-use airports are operated under a private management group. The airports selected to participate in the program include Stewart International Airport in Newburgh, New York; Brown Field in San Diego, California; Rafael Hernandez Airport in Aguadilla, Puerto Rico; New Orleans Lakefront Airport in New Orleans, Louisiana; and Niagara Falls International Airport in Niagara Falls, New York. However, so far, this programme has been met with limited success, with only Stewart International Airport fully completing the privatisation process (Wells and Yang. 2004). However, in 2011, only three airports (Puerto Rico's Luis Munoz Marin International Airport, Briscoe Field in Gwinnett County, and Hendry County Airglades Airport) in the entire US have active applications in the privatisation program (Assaf and Gillen 2012). The enthusiasm toward full airport privatisation has appeared to wane since the late 1990s, as the overall economy of the US has declined. As mentioned above, however, the overall progress has not been very successful as compared with progress in the UK. However, the concepts that drive private enterprises toward competitive and efficient operations are becoming embraced by publicly owned and managed airports. Consequently, more efficient organisational structures and management responsibilities have resulted in more streamlined and efficient airport management organisational structures.

3.2.2. EUROPE: THE UNITED KINGDOM

The UK was the first country to embark on a path of full airport privatisation following the introduction of the 1986 Airport Act. Before this, airports in the UK had depended on subsidies from the UK tax payers. Until the mid-1980s, UK airports were regarded as public utilities to be owned and subsidised by the government. Since then there has been a significant shift and most airports in the UK are now full or partly funded by the private sector.

The trend towards airport privatisation began in the UK around 25 years ago. The consequences of this process provide an important case study for policy makers and practitioners worldwide as they seek to assess whether or not to commercialise, privatise or retain ownership of their airports. Until 1987, most of the airports in the UK were owned by either the central or local governments. The 1986 Airports Act privatised the airports of the British Airports Authority (BAA) and transformed UK municipal airports into commercial companies. Since then, the pattern of airport ownership has evolved unevenly over time as airports have been commercialised and privatised in a variety of forms (Humphreys 1999). The aims of privatisation in the UK were to improve efficiency, reduce government involvement in the industry, reduce subsidies to the public sector, reduce the financial burden on government of the Public Sector Borrowing Rate (PSBR), provide access to private investment, widen share ownership, gain political advantage, and introduce commercially focused management (Morgan 1995). These reasons are similar to those of the US.

Before privatisation, most UK major airports were operated by the BAA, which was established by the passing of the Airport Authority Act 1966 to take responsibility for four state-owned airports. In the next few years, the authority acquired responsibility for Glasgow airport, Edinburgh airport Aberdeen airport and Southampton airport. As part of Margaret Thatcher's moves to privatise government-owned assets, the Airports Act (1986) mandated the creation of the BAA plc as a vehicle by which stock market funds could be raised. The initial capitalisation of the BAA plc was £1,225 million. At the time of privatisation, all of BAA’s issued share capital was sold by the government, except for a retained special golden preference share[3] (which still exists) (Parker 1999). The state corporation was privatised without restructuring on the grounds that a unified company would have the financial resources to fund future investment needs. The main impact of privatisation was not, therefore, in the product market but was rather in the capital market. The BAA became subject to pressure from a threat of takeover by another company that identified possible efficiency gains. At the same time, the continued existence of the government’s golden share in BAA may have reduced the takeover threat.

More recently, the BAA has expanded into international operations, including retail contracts at Boston Logan International Airport and Baltimore-Washington

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[3] This share is often retained only for some defined period of time to allow a newly privatised company to become accustomed to operating in a public environment, unless ownership of the organization concerned is deemed to be of ongoing importance to national interests, for example for reasons of international security (Parker 1999).

International Thurgood Marshall Airport (through a subsidiary called BAA USA, Inc.), and a total management contract with the City of Indianapolis to exclusively run the Indianapolis International Airport (as BAA Indianapolis, Inc.) (BAA 2011). In 2005, BAA took a 75% stake in Budapest Ferihegy, the largest airport in Hungary, which was being privatised by the Hungarian government. In 2007, the decision was made to sell the stake in Ferihegy, which was done when a consortium led by HOCHTIEF AirPort of Germany purchased the stake.

In 2006, BAA was taken over by a consortium led by Grupo Ferrovial. Consequently, the company was delisted from the London Stock Exchange in 2006, and the company name was subsequently changed from BAA plc to BAA Limited. In 2008, Gatwick airport was put up for sale. In October 2009, BAA announced that Gatwick had been bought by Global Infrastructure Partners (GIP). (Grupo Ferrovial 2007; BAA 2011; Gatwick 2011). Furthermore, in March 2009, the UK Competition Commission ruled that BAA must sell Stansted within two years to either Glasgow or Edinburgh airport. In 2012, BAA announced the sale of Edinburgh Airport to GIP, and after losing a case in the Court of Appeal, BAA announced they would sell Stansted in the near future (BAA 2012). This brief summary of the history of BAA shows that the airport ownership can be transferred to the capital market easily.

The second part of the Airports Act (1986) required that all airports with a turnover of more than £1 million in two of the previous three years become companies. Prior to this, airports had been run directly by their local government owners. Under this condition, 16 airports were covered by this part of the Act (Graham 2005). However, the most far-reaching impact of the Airports Act (1986) was to place airports under an ownership structure that enabled local authorities to sell their shares and become fully privatised companies. Although the UK government has never directly forced airports to privatise, the reduction of the money available for public sector borrowing since 1992/3 has forced most airports to seek private capital to finance expansion (Humphreys 1999). There is no doubt that private companies always emphasise their profits. Therefore, the introduction of various commercialised forms of ownership (including in some cases the full privatisation of airports) has led many airport managements to increase their focus on non-aeronautical sources of revenue (Humphreys and Francis 2002b).

The emphasis on commercial revenue has led to the increased development and utilisation of revenue-generating space and the rapid development of airport sites with business parks, hotels, freight facilities and maintenance facilities. However, these changes (as increased retail outlets) can reduce terminal capacity to process passengers (Humphreys and Francis 2002b).

Commercial pressures have also resulted in the pattern of airport ownership becoming increasingly dynamic in the UK, with many significant changes taking place in the ownership and governance of regional airports. Details of the changes at the original 16 airports that were commercialised under the Airports Act (1986) are discussed in Humphreys (1999). In 1997, the Airports Act Part II introduced a mixed pattern of ownership structures (see Figure 3.3). By 1997, four airports were fully privatised (i.e. East Midlands, Bournemouth, Southend and Cardiff) and three airports entered a part public, part private ownership structure (i.e. Birmingham, Bristol, Liverpool). The remaining nine airports remained in public ownership (i.e. Manchester, Blackpool, Norwich, Humberside, Leeds Bradford, Luton, Newcastle, Teesside and Exeter). Since 1997, the private sector has taken an increased role in UK airport ownership structures, and along with this, the rate at which ownership has been transferred from one owner to another has also increased (see Figure 3.4). Only two airports have remained with the same owners. The predominant ownership structure has shifted towards public and private partnerships, with seven airports adopting this structure. Five airports are fully privately owned, while four have remained in public ownership. Detail are provided as follows:

Figure 3.3: The ownership structure of UK airports in 1997

Source: Ison et al. (2011).

Figure 3.4: The ownership structure of UK airports in 2010

Source: Ison et al. (2011).

Table 3.4 shows the trend of ownership in the UK. As mentioned early, in the past 20 years, airport ownership has been transferred several times. Both East Midlands and Bournemouth have moved from the private sector back into full public ownership (i.e. Manchester Airport Group: MAG). Humberside has remained in public ownership, but a majority of its shares are held by the MAG. Birmingham has stayed partly privatised and Liverpool has stayed fully privatised, but the private owners have changed. Exeter and Blackpool have moved from the public sector to the private sector. Meanwhile, Norwich, Leeds Bradford, Durham Tees Valley, Newcastle and Luton have gone from being publicly owned to being partly privately owned. Since 1987, only Manchester airport has retained the same owners. In addition, the airports that were not part of the original 16 have offered commercial services. In a further trend, all but two of the airports are now partly owned by larger (in some cases international) airport groups. As mentioned in the previous section, the privatisation of a public sector entity results in a monopoly. The UK government has tried to take the role of regulator to prevent an enterprise from abusing its position. The most common form of intervention has been the regulation of the price an enterprise can charge for its products or services (Bishop and Thompson 1992). However, the importance of whether or not ownership is public or private may be misplaced. Some people have suggested that the nature of competition and the form of regulation is more important than ownership in achieving the economic aims of privatisation (Graham 2011). Privatisation has been successful in some of its other aims. The amount of public money required to subsidise nationalised industries has been drastically reduced; the strain on public sector borrowing has been removed; access to private finance has been provided, and the role of government has changed from owner/operator to regulator with the power to intervene in the public interest. Privatisation was introduced in the UK to control the PSBR by addressing the inefficiencies of loss-making public sector industries (Pirie 1985). Although the public sector deficit had disappeared by 1987/8, privatisation was still pursued as a politically attractive means to finance tax cuts without reducing public expenditures (Thompson 1990). Given the lack of a case for privatisation in terms of improved efficiency, it appears that privatisation was pursued as an ideology by the UK government. The model shows how a government can privatise swiftly and maintain political popularity. How far then do municipal airports reflect these general trends?

In order to deal with airport privatisation, the UK government authority has attempted to set up several regulations. The principal aspects of these regulations are airport licensing and safety, economic regulations, international obligations, traffic regulation, aviation security and noise. This section looks at the framework for economic regulation of airports. The regulatory system aims to provide safeguards against distortion of the air travel market through predatory pricing or other monopoly abuses by airport operators. It also aims to incentivise cost control and efficiency (Gillen 2011).

Table 3.4: The changing of UK airport ownership

Airport		1980s				1990s										2000s													Ownership transfer	
		86	87	88	89	90	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08	09	10	11	12		
Southampton	SOU	Mr Somer			PdS		BAAplc														Ferrovial								3	
Aberdeen	ABZ	PS	BAA plc																		Ferrovial								2	
Edinburgh	EDI	PS	BAA plc																		Ferrovial							GIP	3	From 04/2012
Gatwick	LGW	PS	BAA plc																		Ferrovial					GIP			2	Global Infrastructure Partners
Heathrow	LHR	PS	BAA plc																		Ferrovial								2	
Standsted	STN	PS	BAA plc																		Ferrovial								2	Announced to sell on 2012
Prestwick	PIK	PS	BAA plc				Prestwick Aviation Holdings Stagecoach											Infratil											3	
Liverpool	LPL	Public Sector				British Aerospace (76%)							Peel Airports (76%; 100% from 2001)																2	
Manchester	MAN	Public Sector				Manchester Airport											Manchester Airport Group (MAG) public enterprise												0	
Humberside	HUY	Public Sector													Manchester Airport and from 2001MAG													Eastern group	2	Announced on 08/2012
EastMidlands	EMA	Public Sector								National Express							MAG												2	
Bournemouth	BOH	Public Sector									National Express						MAG												2	
Cardiff	CWL	Public Sector									TBI										TBI (Abertis)								2	
Belfast	BHD	Public Sector										TBI									TBI (Abertis)								2	
Luton	LTN	Public Sector				30 years management contract with London Luton Airport Operations Ltd From 1998											London Luton Airport Operations Ltd (TBI)				London Luton Airport Operations Ltd (Abertis)								0	
Birmingham	BHX	Public Sector											EuroHub (Birmingham) Limited. (48.25%)																1	
Bristol	BRS	Public Sector											First Group (51%)					MEIF1 (50%); Teachers'(49%)*											2	
Newcastle	NCL	Public Sector															Local government (51%) Copenhagen Airport (49%)												1	
Durham Tees Valley	MME	Public Sector																	Peel Airports (75%)							Vantage Airport Group (65%)			2	
Blackpool	BLK	Public Sector																					MAR	Balfour Beatty					2	Balfour Beatty
Norwich	NWI	Public Sector																		Omnipot (80.1%)									1	
Exeter	EXT	Public Sector																					RCA						1	
Leeds Bradford	LBA	Public Sector																					Bridgepoint Capital.						1	
Inverness	INV	Public Sector				Highlands and Islands Airports Limited																							0	
Newquay	NQY	Public Sector																											0	
London City	LCY	Mowlem									Dermot Desmod											AIG & GIP			GIP(75%)				3	
Doncaster Sheffield	DSA																				Peel Airports								0	

Source: Organised by author.

* Bristol Airport is 50% owned by Macquarie European Infrastructure Fund 1 (MEIF 1), with approximately 49% held by Ontario Teachers' Pension Plan (Teachers').

At present, the CAA's Economic Regulation Group regulates the 45 airports which exceed the £1million turnover threshold under the Airports Act and the Airports (Northern Ireland) Order 1994. The economic regulation of airports by the CAA dates from the Airports Act (1986). The objectives of the CAA are to further the reasonable interests of airport users, to promote the efficient, economic and profitable operation of airports, to encourage investment in new airport facilities to satisfy anticipated user demand, and to impose the minimum amount of regulation consistent with these duties.

When measuring the success of UK airport privatisation and commercialisation against with other countries, it is clear that this has been largely successful in some points (such as encouraging enterprise in the operation of major airports, air transport facilities should not in general be subsidised by the taxpayer and should normally operate as commercial undertakings). However, it is difficult to separate out the impact of commercialisation from privatisation and it can be concluded that much could have been achieved by commercialisation alone. In this the UK experience is very different from the policies which are undertaken in the US. This research can help to find out what kind of ownership can improve airport efficiency.

3.2.3. ASIA: CHINA

Although in 2011, China had 142 civilian airports, the market was skewed towards the largest 10 airports, which together possess a 60% share of passenger volumes. Seven of these are located along the eastern seaboard (i.e. Beijing, Shanghai Pudong, Shanghai Hongqiao, Hangzhou, Guangzhou, Shenzhen, and Hainan). The pattern is similar for cargo, with the five leading airports accounting for 64% of total volume (CAAC 2010). These airports employ nearly 50,000 people and have assets worth approximately US$ 4.8 billion (CAAC 2010). The majority of these airports remain fully government owned through the CAAC and local government entities. In 1984, the Civil Aviation Administration of China (CAAC) was established; prior to this, China had no commercial aviation sector. However, it was not until 1988 that the first airport reform was initiated. The subsequent process can be broadly divided chronologically into three stages (Yang et al. 2008).

In the first stage, between 1988 and 1994, the primary objective was to reform airport management. Previously, the Chinese government had controlled all airport activities through its economic planning institutions. China's economic reforms involved restructuring state-owned enterprises and industries and injecting new impetus into the economy. Through the implementation of the "Temporary Provision of Airport Management" in 1989, airports were separated from airlines. Airports were then defined under the 'Measures to Change the Operational Mechanisms of State-owned Aviation Enterprises' as enterprises to protect airport operation from central government control.

The second stage of reform, which lasted from 1995 to 2001, included the development of airport joint-equity and further localisation reforms. At this time, attention turned to the ownership structure of airports. Many airports began to operate along market lines following the provision of the 'Standardisation Management of Civil Aviation Enterprises' in 1997. Most airports underwent joint-equity reform, and airport businesses activities were extended to capital operations. Several airports were listed on either domestic or foreign stock markets. In a bid to stimulate enthusiasm and interest among local governments in regard to development of the industry, devolution was extended. A total of 35 airports were transferred their management to local administrations during this period.

In the third stage, which began in 2002, the liberalisation of the airport industry accelerated and blanket devolution was implemented. Most of China's airports had established some form of internal governance structure and had become joint-equity enterprises. In 2002, the CAAC transferred ownership to the provincial government. Management control over these jobs and assets largely passed to its provincial offices. Although only a handful of airports were listed or had foreign investments, several airports announced that they would welcome a strategic partner. A number of Chinese airports were looking to foreign investors, not only to provide capital but also to provide international management expertise.

The role of the CAAC has continued to evolve since 2002. Having once owned and managed the entire aviation sector, the CAAC now discharges more administrative and regulatory functions. Today its jurisdiction spans the following areas (Fung et al 2008):

(1) Central planning for airports

The CAAC has the power to approve construction or redevelopment of airports facilities, including terminals and runways. It liaises with other government bodies in the planning of supporting infrastructure.

(2) Setting domestic and international aviation tariffs

The CAAC's control over tariffs means that it retains significant influence over their largest source of revenues. This situation is expected to change and will affect the future financial performance of Chinese airports.

(3) Administering airport construction fees

The CAAC collects these fees in a centrally administered fund and then disburses the money back to the airports.

(4) Setting and monitoring standards

The CAAC formulates all standards governing safety, security and other operational issues within airports.

(5) Airspace administration and air traffic control

The CAAC grants airlines the rights to use certain routes and administers air traffic within China's borders. These functions are likely to remain under the close supervision of the CAAC. The CAAC is also involved in representing China in international negotiations related to civil aviation airspace.

These reforms, which have developed since 1988, have brought about greater opportunities and greater business interest in the sector. In turn, they have dramatically changed the ownership pattern of China's airports. In the last few years, ownership of most airports in China has been transferred from the central government to local authorities. The most profitable airports have been partially privatised and listed on the stock market (e.g. Shanghai and Beijing airports) (Fung and Chow 2011). However, most airports in China are still majority owned by the government and, unlike their counter-parts in other countries, are still highly subject to government intervention in their daily operations and management (in addition to regulatory requirements). The following section describes current types of privatisation methods in China (Yang and Hong 2010):

(1) Foreign investment

After the implementation of a localisation program focusing on ownership transfer from the central government to local authorities, the CAAC has further allowed foreign investors to take equity stakes in China's airports. For example, in April 2005, the Airport Authority Hong Kong (AAHK) agreed to invest a stake of 35% in Hangzhou Xiao Shan International Airport (ranked number nine among Chinese airports by the number of passengers handled). After AAHK's investment in Hangzhou Airport, airports in Ningbo, Nanjing, Chengdu and Kunming were reportedly negotiating with foreign investors on stake sales. In 2005, German airport operator Fraport AG (which manages Frankfurt Airport) signed a strategic partnership agreement to buy 25% of Ningbo Lishe International Airport (Zhang 2008).

(2) Publicly listed company

The extent of airport privatisation in China has been relatively limited compared to that of other countries, especially in Europe. The most common process of privatisation in China has been to issue shares in the stock market to introduce private capital intended to support the expansion and upgrade of airport facilities. In most cases, the local government has remained a majority shareholder and is still in control of the board of the airport company. Since 2000, six Chinese airports (i.e. Shenzhen, Shanghai, Xiamen, Hainan, Beijing and Guangzhou) have been listed on the stock market.

(3) Public Private Partnership (PPP)

In contrast to the core business of passenger terminal management and aircraft handling (i.e. the aeronautical part of aviation), the Chinese government has always been more receptive to opening the market of the non-core aviation business (i.e. non-aeronautical) to private operators, which is considered less essential (such as retail in passenger terminals and ground handling services). Consequently, in China, airport assets and property are usually managed by the airport company, which is 100% or majority owned by the government, while the non-aeronautical part of the airport business is now often contracted out to private companies (Zhang 2008). In China, due to the lack of a legal framework in the management of concessions, the major types of PPP models in commercial activities usually involve short-term sub-contracting of services and mid-term leasing. For example, the retail spaces in Shanghai International Airport are leased out to private operators, and their performance is reviewed regularly. Meanwhile, the maintenance of their terminal facilities is contracted out. Shanghai International Airport has also established a joint-venture company with Frankfurt Airport to provide training to their airport employees (Fung and Chow 2011). These are examples of attempts by the government to partially privatise the operations and maintenance of airports, and they demonstrate that the Chinese government is continuing its effort to develop a market economy. This is also the first step in the process of granting more autonomy to state-owned enterprises.

(4) The airport corporations

The Chinese government has allowed mergers and acquisitions between airports in the last few years. Consequently, several large airport corporations have been formed in China to achieve economies of scale and the synergy by which to improve management and financial strength. Although the size of most airport corporations in China is still relatively small when compared with other international airport operators (e.g. BAA), the creation of airport corporations managing more than one airport signifies the Chinese government's effort in promoting operational autonomy and a strategy to achieve balanced developments between the regions (Gong et al. 2012). Capital Airports Holding Company (CAH) can be considered a success story of airport mergers and acquisitions in the Chinese airport industry. At the end of 2008, CAH was holding stakes worth RMB 67 billion in more than 30 airports in China located in many parts of the country (Yang and Hong 2010).

After 20 years of evolution, airport ownership in China has significantly diversified. Some Chinese airports are built and owned by municipalities while others are owned and controlled by provincial governments. Some have been sold or handed over to airport groups while others have been incorporated and have become leading to cross-region and cross-industry multiple owners. There have been domestic and international Initial Public Offerings (IPOs) of several Chinese airports (Gong et al. 2012). Meanwhile, foreign ownership by joint venture has started to be introduced. This process of commercialisation and privatisation has gradually transformed airports into financially self-sufficient and profit-making businesses. China's airports are no longer run as municipal facilities maintained by subsidies from central or local governments. Table 3.5 shows the ownership structure of Chinese major airports.

Table 3.5: Major airports in China

Ownership	Airports
Central government ownership	All the airports in Tibet; All the airports under Beijing Capital Group including Capital Airport and Tianjin Airport; All airports under Hubei, Jiangxi, Jilin, Guizhou, Chongqing airport groups and Heilongjiang.
Central government controlled - mixed ownership	Capital Airport*, Shenyang Airport and Dalian Airport.
Local government ownership	Trunk airports and all feeder airports in most provinces (e.g. Shanxi, Shaanxi, Hunan, Henan, Yunnan, Harbin and Xinjiang, Yinchuan and Qinghai Airports, etc).
Local government controlled mixed ownership	Shanghai, Baiyun**, Xiamen*, Shenzhen*, Hangzhou*, Zhuhai* , Meilan **

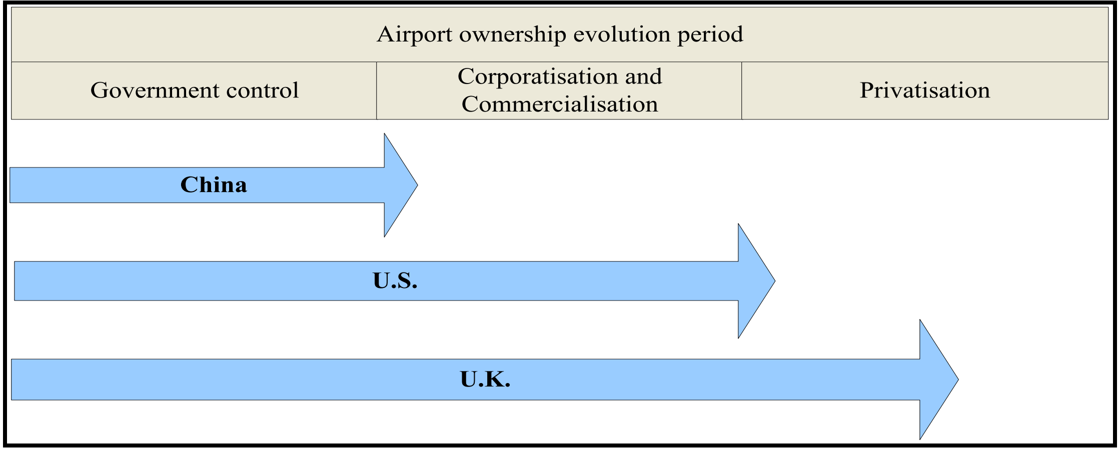
Source: Yang et al. (2008). Organised by the author.
Note:*Airport has foreign investment. ** Airport has airlines investment.

Reforms in China have transformed some airports from loss making entities that are reliant on large public subsidies into profitable, customer-orientated businesses. Airports have been able to diversify and to put more emphasis on expanding their non-aeronautical activities (Yang et al. 2008). However, despite these changes, such as foreign investment, publicly listed airport companies, airport corporatisation, and public private partnership, China's aviation industry still lags behind those of many developed countries, and it continues to face a number of challenges (such as a low-cost airline wave). In particular, institutional reform has been slow, and it has often not supported larger policy objectives. Unbalanced development among different regions is problematic, and many airport operations remain unprofitable. In the long-term, central and local authorities may have to allow more diversification and commercialisation of airport ownership structures and further reduce perceived commercial risk. At the same time, the lack of transparent performance variables to gauge policy affects is hampering objective assessment of reform. This research can provide an opportunity to determine whether it is appropriate to undertake a Western style airport privatisation policy in Eastern airports.

3.3. SUMMARY

The review of the changing nature of airports in this chapter has described the changing patterns of airport ownership in three very different countries. The airport ownership patterns in the periodicity of airport ownership and governance evolution that have been described in this chapter (see Section 3.1) can help us to understand the current airport ownership trends around the world. Figure 3.5 shows the evolution of airport ownership structure among these three countries.

Figure 3.5: Evolution of airport ownership structure



Source: Organised by author.

Airports in China are currently in the early stage of a second period of development, due to the outsourced nature of airport operations and the government still retaining ownership. Since the late 1990s, the Chinese government has embarked on a policy of floating state-owned airlines and airports in the stock markets in order to improve their efficiency and performance. Even after a localisation program which was started in 1988 and completed in 2003, among these 142 commercial airports, so far, only six Chinese airport companies have been listed on stock exchanges in Hong Kong, Shanghai and Shenzhen (Gong et al. 2012). However, the state still holds majority ownership in these listed companies. When comparing the evolution in China with the other two countries, the FAA in the US has only tried to privatise a few airports, and most of the day-to-day operations in the majority of US airports have been commercialised. Therefore, airport ownership evolution in the US could be said to be in the early stage of privatisation. In addition, UK airports have been transferred between owners several times. In this case, the evolution period should be classified as being in the middle of privatisation.

Sample airports from different ownerships are selected for the purposes of this research to answer the second Research Question 2. Therefore, after reviewing the changing nature of airports in this chapter, we can see that US airport ownership structures are very similar. Consequently, the sample airports should be selected from Europe and the Asian-Pacific region.

CHAPTER 4

RESEARCH DESIGN
AND METHODOLOGY

This chapter examines the methodological considerations on the understanding of airport efficiency by using different analysis methods. It connects the previous chapters and the following chapters, which develops the research structures and presents the entire analytical process of this research. This chapter consists of eight sections. A general discussion on research philosophies, approaches, and strategies is presented in Section two. The data analysis methods that are used in this study are described individually from sections three to six. The data collection methods that are adopted in this study are described in Section seven. The research framework of this study is discussed in the last section.

4.1 RESEARCH DESIGN

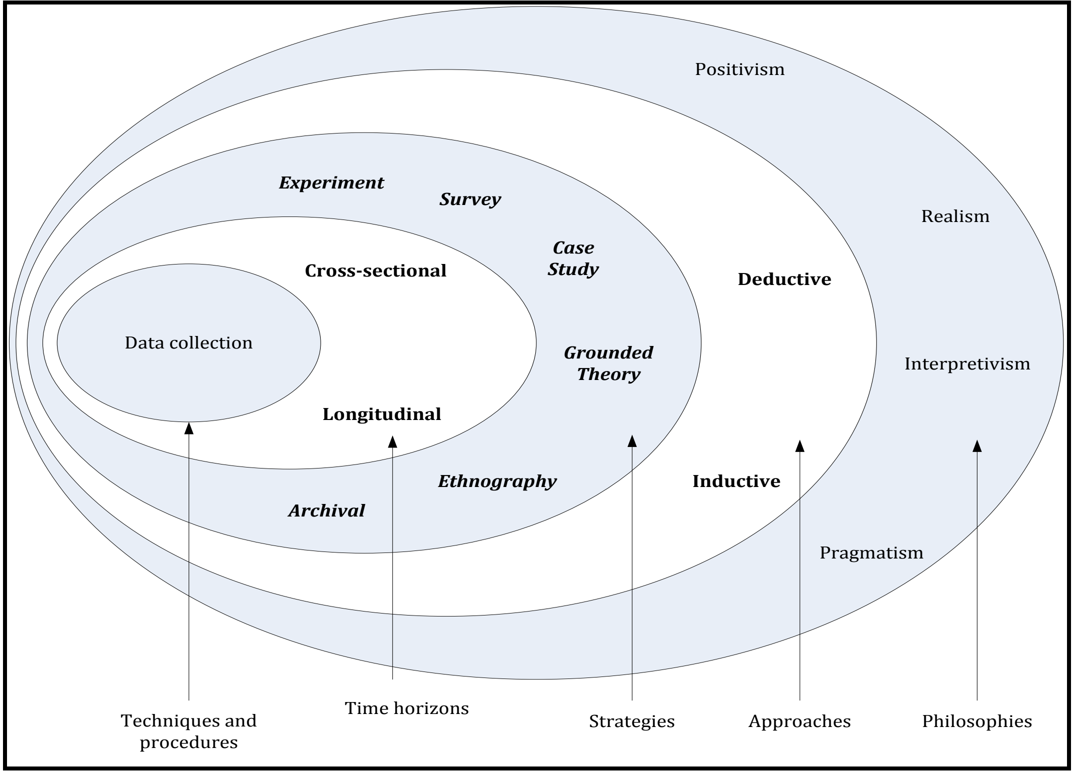
Churchill (1976) compared research design to the architect's blueprint for a house, which is nothing more than the framework for research. The choice of research design reflects the decision about the priority that is given to a range of dimensions of the research process (Bryman and Bell 2011). In essence, a research design provides guidance for the collection and analysis of the data in a study, which ensures the relevance of the work to the proposed problem and employment of economical procedures (Churchill and Iacobucci 2002). This will influence the choice of methodology, the data collection method that is used, and the justifications of the research outcomes. Following the development of these concepts, the next step is to identify an appropriate research design to structuralise and conceptualise the newly evolved disciplines of the research.

In academic research, methodology is defined as a body of knowledge that allows a researcher to underpin the research questions through the use of various types of evidence that can be gathered (Clark et al. 1984). According to Avison and Fitzgerald (1995 p. 63):

> *"a methodology is a collection of procedures, techniques, tools, and documentation aids.... But a methodology is more than merely a collection of these things. It is usually based on some philosophical paradigm; otherwise it is merely a method, like a recipe."*

To identify the presuppositions and consequences of the applied procedures, a research methodology is important to any study (Miller 1983). Näslund (2002) recommended that the selection of a research method should be based on the research paradigm, or question, due to the fundamental nature of the research processes, which are generally involved with a particular research strategy or method. The following section presents the philosophical position and approach of this research, which highlights the influence of the research method selection. Saunders et al. (2009) described the research process as being like an onion, where assumptions must be made at each individual stage of the research approach, and where each of these stages is represented as a layer of an onion (as showed in Figure 4.1). The research process that is used in this current study is described from the outside to the inside of the onion.

Figure 4.1: The research onion



Source: Saunders et al. (2009); Organised by author.

4.2 RESEARCH PROCESS APPROACH

Figure 4.1 shows that there are five major categories in the research process, which are: research philosophies, research approaches, research strategies, time horizons, data collection, and data collection techniques and procedures. Research philosophy is concerned with the distinction of science from non-science, which procedures should be followed, and establishes the conditions for a scientific explanation that should be established (Smith 2000). The research approach is defined as a choice between testing and building theory. Research strategy is a general plan for answering the research questions (e.g. survey or case study). The time horizon is related to a snapshot or diary approach. Finally, the data collection method chooses how the data will be gathered (Saunders et al. 2007).

4.2.1 RESEARCH PHILOSOPHY

A research philosophy is defined as an assumption of how knowledge is developed and analysed (Saunders et al. 2007; Maylor and Blackmon 2005; Levin 1988). The axiom of “knowledge”, which is driven by research paradigms, can be explained in terms of ontology, epistemology, and methodology (Denzin and Lincoln 1994; Guba and Lincoln 2005).

Ontology is the branch of metaphysics that is concerned with the nature of existence. Social ontological considerations are mainly concerned with questions about the nature of reality; for example, whether an objective reality exists or not, or whether social entities can and should be considered as social constructions built up from the questions and actions of social actors (Bryman and Bell 2011). There are two aspects of ontology, which are objectivism and constructivism. Objectivism is an ontology which asserts that social phenomena and their meanings have an existence that is independent of social actors, while constructivism is a position which asserts that social phenomena and their meanings are continually being accomplished by social actors (Saunders et al. 2009).

Epistemology is concerned with the question of what is regarded as acceptable knowledge in a discipline. It asks whether the principles, procedures, and ethos of natural science can and should be applied to the social world. Broadly speaking, there are two opposing philosophical perspectives on epistemological consideration, positivism and interpretivism (Bryman and Bell 2011). Positivism share some features with the natural sciences in which it is believed that natural scientific methods can, and should, be extended to the study of human mental and social life. It is also believed that once reliable social scientific knowledge has been established, it will be possible to apply it to control or regulate the behaviour of individuals or groups in society (Benton and Craib 2001). On the contrary, interpretivists share a view that the subject matter of the social sciences is fundamentally different from that of the natural sciences.

Methodology examines how we gain knowledge about the world, and Guba and Lincoln (1994) indicated that a methodological question is constrained by both ontological and epistemological considerations. Saunders et al. (2000) also claimed that a research philosophy is a rather profound thought that has not normally been paid attention to, but which governs the way that researchers go about doing research.

Guba and Lincoln (2005) pointed out that there are three main research paradigms that can be explained through ontological, epistemological or methodological positions, namely: positivism, critical realism and constructivism (see Table 4.1).

Table 4.1: Comparisons of philosophical research paradigms

Elements	Positivism	Critical Realism	Constructivism/ Interpretivism
Ontology	'Naïve realism', in which an understandable reality is assumed to exist, which is driven by immutable natural laws. The true nature of reality can only be obtained by testing theories about actual objects, processes or structures in the real world.	Critical realism – 'real' reality but only imperfectly and probabilistically apprehendable.	Relativism – local and specific constructed realities. The social world is produced and reinforced by humans through their actions and interactions.
Epistemology	Dualistic/objectivist. Verification of hypothesis through rigorous empirical testing. Search for universal laws of principles. Tight coupling among explanations, predictions and control.	Modified dualist/ objective. Critical tradition/ community. Findings probably true.	Transactional/ subjectivist. Understanding of the social world from the participants' perspective through interpretation of their meanings and actions. Researchers' prior assumptions, beliefs, value and interests always intervene to shape their investigations.
Methodology	Hypothetical-deductive experiments/ manipulative. Verification of hypotheses. Mainly quantitative methods.	Modified experimental/ manipulative. Falsification of hypotheses. May include quantitative methods.	Hermeneutical/ dialectical. Interpretive case study. Action research. Holistic ethnography.
Inquiry Aim	Explanation: prediction and control		Understanding, reconstruction.
Nature of Knowledge	Verified hypotheses established as facts or laws.	Non-falsified hypotheses that are probable facts or law.	Individual and collective reconstructions, sometimes coalescing around consensus.
Knowledge Accumulation	Accretion – "building blocks" adding to "edifice of knowledge": generalisations and cause-effect linkages.		More informed and sophisticated reconstructions. Vicarious experience.

Source: Guba and Lincoln (2005).

In the past, research into airport performance has been predominantly influenced by economic approaches (i.e. mathematical modelling, simulation and sensitivity analysis) and, to a lesser degree, by behavioural approaches (i.e. questionnaires, interviews and case studies) (Lai et al. 2012). Both approaches are primarily based on the scientific approach of positivism (Mentzer and Kahn 1995). If the research reflects the principle of positivism, then the researcher will adopt the philosophical stance of the natural scientist. Saunders et al. (2007) advised that positivist researchers prefer working with an observable social reality and that the end product of this research is a law-like generalisation similar to those produced by physical or natural scientists. A highly structured methodology is expected to allow researchers to quantify their observations and to analyse those observations through complicated statistical techniques (Saunders et al. 2007). Positivistic research revolves around implicit assumptions which formulate a reference framework by which to understand social reality (Giddens 1974).

Whatever the outcome of a positivist social investigation, the goal of analysis can and must be able to formulate law or law-like generalisations of the same kind as those that have been established in relation to social reality (Giddens 1974). Generally, the positivist approach focuses on the testing of theories and provides new material for the development of laws. There are strong connections between theory and research, which carries the implication that "*it is possible to collect observation in a manner that is not influenced by pre-existing theories*" (Bryman 2003 p.14).

As much of the debate is based on how methods are developed in natural science and transferable to the social sciences, the positivist approach gives a clear sense of separating subjective and objective data interpretation (McKenzie 1997). Under these assumptions, it is believed that social phenomena can be scientifically observed and measured. Along with the emphasis on objectivity, the attained knowledge through scientific methods is viewed as resulting in greater strength in terms of reliability. Furthermore, the positivist approach asserts that results based on a data set will be bias-free (In the current context, bias is commonly caused by personal interpretations and values that may influence conclusions drawn from a set of data). On the other hand, constructivism/interpretivism views of knowledge can only be reached through understanding of subjective meanings in social actions.

In between these two extremes (positivism and constructivism / interpretivism), another emerging research paradigm is critical realism, which views the world as having three components namely: reality, actual and empirical (Sayer 2000). A critical realist believes that the existence of the 'true' domain involve objects and structure which requires casual power to be uncovered. However, the statement of 'truth' is not treated as an absolute matter. Instead, a mechanistic form, such as a relationship or the degree of practical adequacy, is more involved in uncovering the logic (Sayer 2000). According to Sayer (2000), critical realism acknowledges that social phenomena are intrinsically meaningful, and hence that meaning is not only externally descriptive but also constitutive.

In comparison to positivism, a critical realist does not consider 'actual' as a complete representation of the 'real'. According to Reed (1997), social action is the results of the choice of agents, which is influenced by the generative mechanism of structures. A critical realist will not only explain the outcomes but also will reference the impacts of the specific conditions or context. Therefore, the results from the activation of structure at one point in time might not be replicated in the future due to the conditions in which decisions are made.

In retrospect, qualitative researchers are greatly influenced by different intellectual traditions, whereas quantitative researchers are strongly influenced by a natural science approach to what should count as acceptable knowledge (Bryman and Bell 2007). With a particular emphasis on the accumulation of knowledge and discrete steps that follow forms of a pattern, the current research falls into the positivist paradigm. The ontological position of the current research suggests that reality is an external objective which exists beyond our knowledge and comprehension. In this research, transport and logistics management are viewed as an objective entity, and therefore a decision was made to adopt an objectivist stance to the study of particular aspect of logistics and transport management. It is also believed that the social world is constructed through people's experience and knowledge and that only a certain facet of truth can be encapsulated as opposed to the whole phenomenon. In essence, philosophical paradigms have demonstrated ways of knowing and understanding the social world.

According to the literatures review in Chapter 2, the essential assumption of an airport is that airports are auxiliary facilities and that their functions are to support airlines and transportation industries. Consequently, airports are required to offer efficient services to maintain the competitiveness of these industries. Many positivist researchers assume that airports, airport operation systems, or airport industries are tangible objects which are independent of society. They do not consider the human factor as being one of the determinants affecting airport performance. They attempt to find regularities and general laws in airport management and often adopt quantitative methods that rely on numerical and secondary data, and they select their variables through a literature review. In addition, they formulate a production function using econometric techniques and advanced efficiency analysis tools. Therefore, their definition of airport performance can be identified as following a positivistic perspective.

This positivistic perspective could be considered to be influenced by the critical realist approach, which attempts to study the existence of phenomena in the natural world. Critical realism argues that a common approach can only reflect an environmental change which corresponds to the empirical or actual level; it cannot recognise the structural and functional changes which correspond to the real level of reality. This approach also argues that airports have become pivotal nodes and will play a crucial role in the logistics chain, while the previous approach suggests that airport services are offered by a demand that is derived from other players in the logistics chain. Therefore, a critical realist approach suggests that airports are situated in the centre of a performance measurement framework as a point linking the members of a logistics chain. The methodology of critical realism tends to deploy qualitative methods, where critical realism mainly requires interpretive and qualitative methods to explain mechanisms and structures. However, there is only limited evidence in the literature for the use of this approach on airport performance evaluation and in port performance evaluation. Two relevant studies about this philosophy in regard to airport performance are summarised below in Table 4.2.

4.2.2 RESEARCH APPROACH

This section aims to examine the decisions involved in selecting a proper research approach based on the positivist research paradigm. As noted earlier, positivist researchers focus on explicit testing of theories or hypotheses with actual objects, processes, or structures in the real world (Guba and Lincoln 2005). Therefore, the first decision that is to be made is whether the research should use a deductive approach or an inductive approach (Saunders et al. 2007).

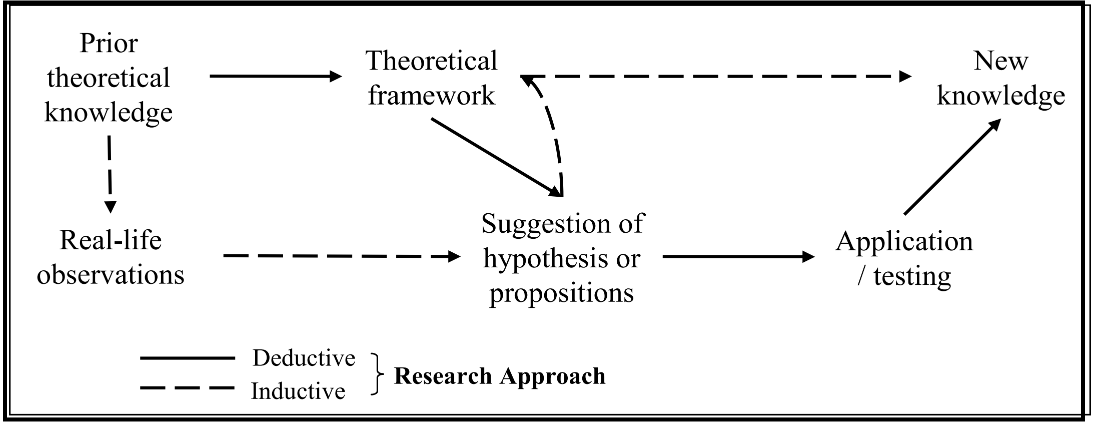
Table 4.2: Critical realist approach of airport efficiency evaluation research

Authors	Methodology	Aims of Research	Objects of Research
Francis et al. (2002)	Semi-structured face-to-face interviews.	This paper examines how benchmarking is used by airport managers as a means of internal performance comparison and improvement.	Interview of airport managers from European airports with over one million passengers per annum (sample size around 200).
Fodness and Murry (2007)	In-depth interviews Focus group Verbatim comments.	The purpose of this paper is to contribute to the development of a conceptual model of service quality in airports by conducting an empirical investigation into the passengers' expectations for this service industry.	In-depth interviews: Passengers in terminal waiting areas of a major USA South-western airport (100 passengers). Focus groups: Frequent flyers in Los Angeles, Dallas and Miami. 72 frequent flyers (six focus groups in total and two in each location). Verbatim comments: Visitors to the web site of a major South-Western airport (1,500 comments).

Source: Organised by author.

The deductive approach is a theory testing process, which commences with an established theory or generalisation and seeks to determine if the theory applies to specific instances. The inductive approach is a theory development process that starts with observations of specific instances and then seeks to establish generalisations about the phenomenon under investigation (Spens and Kovács 2005). The inductive approach (which is also known as the logic of the ethnographer) is the mirror image of the deductive approach. Therefore, theory is the outcome of the research, which involves portraying generalisable inferences out of observations (Bryman and Bell 2003). Research using an inductive approach is likely to study a small sample of subjects, while the deductive approach studies a large number of subjects (Saunders et al. 2007). Knowledge through literature is not necessarily needed at the starting point; instead, empirical observations of the world through logical argumentation are used to lead to theoretical generalisation (Spens and Kovács 2006). The general differences in these two approaches are presented in Figure 4.2 and Table 4.3. The distinct differences between the deductive and inductive approaches are to be found at the starting point of the research process, the aim of the research, the point in time at which hypotheses or propositions are developed, and whether they are further applied or not (Spens and Kovács 2006).

Figure 4.2: The difference between a deductive and an inductive approach



Source: Spens and Kovács (2006).

Table 4.3: Differences between a deductive and an inductive approach

Deductive Approach	Inductive Approach
• Scientific principles. • Moving from theory to data. • The need to explain causal relationship between variables. • The collection of quantitative data. • The application of controls to ensure validity of data. • The operationalisation of concepts to ensure clarity of definition. • A highly structured approach. • Researcher independence from what is being researched. • The necessity to select samples of sufficient size in order to generalise conclusions.	• Gaining an understanding of the meanings that humans attach to events. • A close understanding of the research context. • The collection of qualitative data. • A more flexible structure to permit changes in research emphasis as the research progresses. • A realisation that the researcher is part of the research process. • Less concerned with the need to generalise.

Source: Saunders et al. (2000).

This research adopts a deductive approach, which seeks to test the relationship between airport ownership and efficiency. Deductive positivism is often regarded as the predominant research approach, which is also true in logistics and transport research (Naslund 2002; Aastrup and Halldorsson 2008; Wagner and Kemmerling 2010). By using a deductive approach, a researcher can firstly generate a probability sample from the entire population with a known degree of accuracy. Secondly, the operationalisation of complex constructs with establishment of casual links between the constructs of interest can be simplified. Because the deductive approach is widely used within transportation research, it is unlikely that the research will be misunderstood and subsequently under-valued.

Another key consideration is to decide the purpose of the present study; that is, whether it is explanatory, exploratory or descriptive. Saunders et al. (2007) described the three classifications of research purposes as: firstly, explanatory studies, which aim to establish causal relationships between variables in a situation or a problem; secondly, exploratory research, which aims to explore new insights, ask questions, and assess phenomena in a new light; and thirdly, descriptive studies, which aim to portray an accurate profile of persons, events or situations. The distinctions between these purposes are not absolute, and more than one purpose can be found in any given study depending on the research question (Churchill and Iacobucci 2002). An explanatory study (which is also known as a causal study) conducts experiments to investigate the cause and effect of two or more measured variables (Churchill 1976). Evidence is provided in regard to a structural causal relationship between variables by means of concomitant variations and time order, which results in the elimination of other possible explanations (Churchill and Iacobocci 2002).

An exploratory study operates is a more flexible and creative way to discover unexpected meanings (Kinnear and Taylor 1991; Saunders et al. 2007). This is particularly helpful in clustering a vague problem statement into smaller, more precise sub-problem statements in the form of specific hypotheses. Exploratory research is appropriate to problems about which little is known. In addition, it allows researchers to be flexible with respect to the methods used for gaining insights and developing hypotheses (Churchill and Iacobocci 2002).

Unlike both explanatory and exploratory studies, a descriptive study acts as an extension of (or a forerunner to) exploratory or explanatory study (Saunders et al. 2007). A descriptive study is used to describe the characteristics of certain groups, to estimate the proportion of people in a specified population who behave in a certain way, and to make specific predictions (Churchill 1976). Churchill and Iacobucci (2002) emphasised that a good descriptive study must presuppose existing knowledge in regard to the phenomenon studied. In direct contrast to an exploratory study, a descriptive study requires clear specification and is arguably more rigid.

Regarding to this thesis, exploratory study would be appropriate in investigating the under-explored gap in between airport privatisation policy and airport efficiency with the use of precise measurements through application of DEA and AHP data analysis techniques, possibility of inconspicuous result would hinder the overall research outcome.

4.2.3 RESEARCH STRATEGY

Quantitative and qualitative studies form two distinctive clusters of research strategy. The distinction goes beyond the fact that quantitative researchers employ measurement and that qualitative researchers do not (Bryman and Bell 2011). Quantitative research emphasises quantification in the data collection process; its analysis entails a deductive approach, and it incorporates the practices and norms of positivism. Meanwhile, qualitative research emphasises words rather than quantification in the data collection process, its analysis entails an inductive approach, and it tends to emphasise the ways in which individuals interpret their social world. With regard to research strategy, from the viewpoint of Bryman and Bell (2009), this research adopts a quantitative strategy to evaluate airport performance by using quantifiable secondary data.

From other researchers' viewpoints, research strategy means a general plan of how to answer the research questions that are established by the researcher (Saunders et al. 2007). A variety of strategies are presented (as shown in Table 4.4). There are six commonly used research strategies (i.e. experiment, survey, case study, grounded theory, ethnography, and archival research), which are described below.

An experimental research strategy measures the efforts of manipulating one variable on another (Robson 1993). A survey collects information in a standardised form from groups of people (Robson 1993). In addition, a survey is an effective tool to get opinions, attitudes and descriptions as well as cause-and-effect relationships (Ghauri and Grønhaug 2002). A case study develops detailed intensive knowledge about a single case or a small number of related cases (Robson 1993). Grounded theory generates a theory from data gathered by a series of observations. Theory is grounded in a continual reference to the data (Saunders et al. 2007). Similar to a case study, ethnography, through involvement with a group, seeks to provide a written description of the implicit rules and traditions of that group (Robson 1993). The last research strategy, archival research, makes use of administrative records and documents as the principal source of data (Saunders et al. 2007).

AHP is adopted in this research to obtain weights of variables; hence, a survey is employed as part of the research strategy. In addition, DEA is used to calculate airport efficiency by analysing secondary data; consequently, archival research is also considered to be an appropriate research strategy for use in this research.

Table 4.4: Research strategy and data collection method

Literature	Research strategy	Data collection method
Yin (2003)	Experiment Survey Case study Archival analysis Historical analysis	Documentation Archival records Interviews Direct observations Participant observation Physical artefacts
Thomas (2004)	Experiment Survey Case study Ethnography Action research	Questioning Observation Documentation Recording
Saunders et al. (2007)	Experiment Survey Case study Grounded theory Ethnography Archival research	Observation Interviewing Questionnaire survey Secondary data
Bryman and Bell (2011)	Quantitative Qualitative	Structured interviewing Self-completion questionnaire Structured observation

Source: Organised by author.

4.2.4 TIME HORIZON

An important question to be asked in planning a research is if it is to be carried out at a particular time, or, whether it is a series of representations of events which are taken over a given period. According to Bryman and Bell (2007), a cross-sectional design is built on the idea that it is a social survey that connects in peoples' minds with questionnaires in regard to two or more variables at a particular time. A cross-sectional design is the most widely used design in social research when quick results are required (De Vaus 2001).

In longitudinal design, the data are collected for each item or variable for two or more distinct time periods. The subjects or cases analysed are the same, or at least comparable, from one period to the next, and finally, the analysis involves some comparisons of data between or among the periods under consideration (Burton 2000).

In this research, the researcher seeks to describe the impact of airport performance in different regions in the same year. Therefore, positing the key determinants for designing the time horizon (i.e. time constraints, the abilities of subjects and the nature of the research objectives and questions) means that a cross-sectional study design with archival research strategy is adopted for use in this research.

4.3 DATA ANALYSIS METHODS

In the past, the efficiency of airports has generally been measured and compared on the basis of the number of passengers, the amount of cargo, and the number of aircraft movements. While this approach is valid, there is an assumption that all inputs and outputs have equal weighting. In reality, however, the relative importance of each of these inputs may vary between different airport stakeholders. This section aims to describe which kinds of data analysis methods are adopted in this research.

To bring in qualitative judgements, MCDM will be used. Referring to section 2.2, MCDM includes AHP, TOPSIS, PROMETHEE, and ELECTRE. Among these methods, only TOPSIS and AHP were found to be used in airport efficiency evaluation research. This research uses AHP presented as follows:

Tremendous efforts have been spent, and significant advances have been made towards the development of numerous MCDM methods for solving different types of decision problems (Yeh et al. 1999; Triantaphyllou 2000). Despite this, there is no universally accepted approach for the general MCDM problem (Yeh et al. 2000), and the validation of the decision outcome remains generally an open issue. The outcome is quite often dependent on the method used. Besides, methods should enhance the Decision Makers' (DMs') learning about the problem (Zeleny 1983) as well as eliciting the DMs' preferences (French, 1980).

The AHP is an appealing methodology by which to evaluate qualitative and quantitative criteria systematically (Saaty 1980). It is very flexible in regard to allowing the decision maker to structure the hierarchy to fit individual needs and preferences and enables the DM to develop a trade-off among multiple criteria implicitly in the course of structuring and analysing a series of pair-wise judgement comparison matrices

(Zeleny 1983). Moreover, the AHP can combine tangible and intangible aspects to obtain, in a ratio scale, the priorities associated with the alternatives of a problem. Therefore, the major strength of the AHP is that it enables the systematic structuring of any complex multi-player, multidimensional problem (Saaty 1980; Zelen 1983).

In Section 2.2, the literature showed that DEA, SFA and TFP have been applied widely in airport efficiency evaluation literature, with DEA being the most popular. In regard to SFA, some of the advantages over DEA are that it accounts for noise and can be used to conduct conventional tests of hypotheses (Coelli et al. 2005). It also has some disadvantages, such as the need to specify a distributional form for the inefficiency term and the need to specify a functional form for the production function (or cost function). TFP is usually measured by using either least squares econometric methods or other index numbers. Some of the advantages of index numbers over least-squares econometric methods are that only two observations are needed; they are easy to calculate and the method does not assume a smooth pattern of technical progress, while the principal disadvantage is it requires both price and quantity information (Coelli et al. 2005).

This research (as mentioned in Chapter 1) attempts to establish an objective and reliable AEES and also is an attempt to compare the results generated by using different analysis methods. Among these frontier analysis methods, DEA is the one that can easily be combined with other methods and is the most reliable approach. Some of the strengths of DEA include (Lewin and Minton 1986; Chen and Yen 2005):

- DEA analysis can combine many measures without the need to set prior weights for various parameters to produce an overall efficiency measure.
- In contrast to conventional econometric techniques, DEA generates an intangible ‘efficiency’ frontier to make a comparison of efficiency in an optimal sense. Therefore, a slack analysis, which provides the inefficient DMU information necessary to raise outputs and reduce inputs in order to improve their efficiency, can be easily conducted.
- In DEA, two or more input and output measures can be specified simultaneously. In addition, since DEA is unit invariant, no normalisation or transformation of the input and output variables are required.

Despite the many strengths of DEA, there are also some limitations (Lewin and Minton 1986; Bowlin 1987; Zhang and Bartels 1998; Cooper et al. 2006; Lozano and Gutierrez 2011):

- The result will be influenced by the homogenous level of the measured DMUs.
- DEA cannot handle negative data.
- DEA does not consider random error and accepts instead that all errors come from inefficiency; hence, the DEA is easily influenced by extreme values. If there are significant variations between DMUs, then the efficiency score will be significantly changed.
- The quantity of DMUs and the choice of input and output variables will influence the DEA efficiency score, which causes a change of the feature and the position of the efficiency frontier; therefore, the response is quite sensitive. Accordingly, choice of the key element for DEA is very important.
- An insufficient number of DMUs for a DEA model will tend to rate all DMUs 100% efficient because of an inadequate number of degrees of freedom. A rule of thumb for maintaining this when using DEA is to obtain at least two DMUs for each input or output measure.

4.4 ANALYTICAL HIERARCHY PROCESS (AHP)

Decision making within the real world inevitably includes the consideration of evidence that is based on several criteria, rather than on a preferred single criterion (Beynon 2002). In business, decision making practices increasingly involve multi-criteria decisions that are made by groups of DMs (Triantaphyllou 2000). The solution to a multi-criteria decision problem can provide a recommendation to DMs who are faced with a choice of Decision Alternatives (DAs). Multi-Criteria Decision Making (MCDM) is currently one of the most well-known branches of decision making methodology (Salo 1993) (details are described in Section 2.2.2).

4.4.1 THE RATIONALE OF AHP

The AHP is a decision making technique that was developed by Thomas Saaty in the 1970s. It depends on the study of both mathematics and psychology. The first step of AHP is to decompose the elements that are related to the decision into goals, criteria, and alternatives. The next step is to study these elements using both qualitative and quantitative analysis techniques (Ramanathan 2001). The AHP method is widely used in both individual and group decision-making environments (Bolloju 2001). It is also used to determine the relative ranking of DAs. It is built on human-beings' intrinsic ability to structure their perceptions (or their ideas) hierarchically, to compare pairs of similar things against a given criteria or a common property, and to judge the intensity of their preference for one thing over another (Forman and Peniwati 1998). These pair-wise comparisons are determined by using scale values, which are processed in order to derive their final weight values (priority values). However, in many decision problems the information available from the DMs is often imprecise due to the use of inaccurate estimates of criteria values and due to subjective errors that arise from the inconsistent judgement of DMs (Pan and Rahman 1998).

4.4.2 THE AHP PROCESS

The AHP is aimed at integrating different measures into a single overall score for ranking DAs (Önü and Soner 2008). Its main characteristic is that it is based on pair-wise comparison judgements. The operational process is illustrated in Figure 4.3. There are five main steps in the AHP (Saaty 2008):

(1) Define the decision object.

(2) Classify the variables which affect the decision and build a multi-level structure. The top level is the goal of this decision; the intermediate levels are criteria and sub-criteria for comparing DAs, and the lowest level are alternatives (as shown in Figure 4.4).

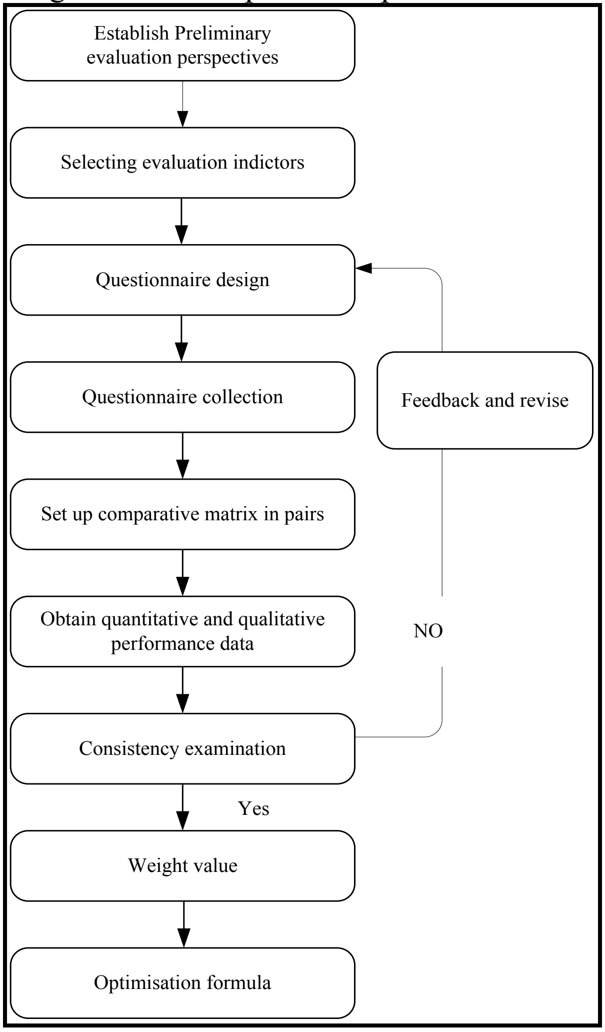
(3) Make comparisons between each criterion in an upper level and the same criterion in the level below it in terms of relative importance; that is, forge a set of pair-wise comparison decision matrices. Let *A* represent an *n* x *n* pair-wise comparison matrix, which can be expressed as:

$$A = [a_{ij}] = \begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ 1/a_{12} & 1 & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ 1/a_{1n} & 1/a_{2n} & \cdots & 1 \end{bmatrix}, \qquad (4.1)$$

where $a_{ii} = 1$ and $a_{ij} = 1/a_{ji}$, $i, j = 1, 2, \dots, n.$
$a_{ij} > 0$

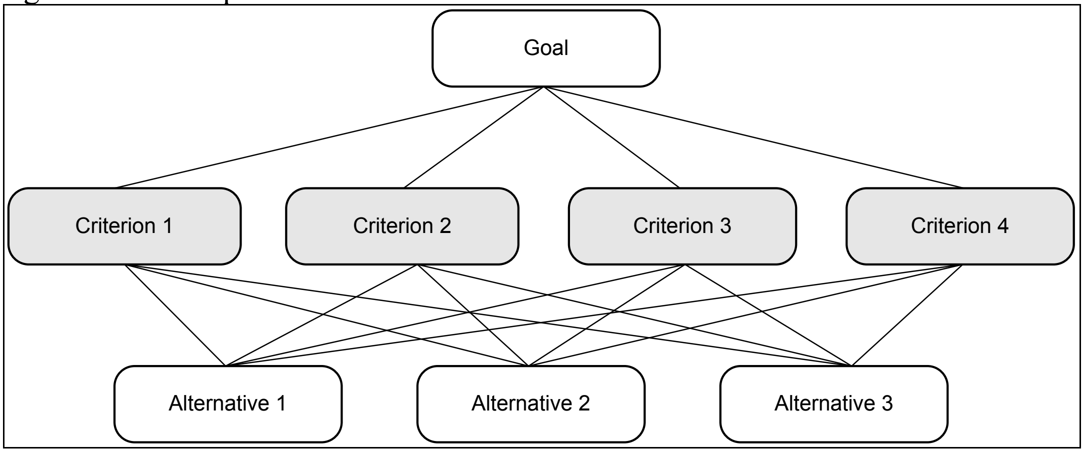
Let $C_1, C_2, \cdots, C_n$ denote the set of criteria, while a_{ij} represents a quantified judgement on a pair of criteria C_i and C_j. Saaty (1980) constituted a measurement scale for pair-wise comparisons. In addition, in order to create a contrast indicating the degree to which one criterion is more important than another, a scale of numbers (see Table 4.5) is settled. The values of 1, 3, 5, 7, and 9, in the original 1-9 scale by Saaty (2008), represent equal importance, weak importance, essential importance, demonstrated importance, and extreme importance, respectively; while the values 2, 4, 6, and 8 are used to compromise between the values referenced above.

Figure 4.3: The operational process in AHP



Source: Saaty (2008); Organised by author.

Figure 4.4: A simple structure of AHP



Source: Organised by author.

Table 4.5: The fundamental scale of absolute numbers

Intensity of Importance	Definition	Explanation
1	Equal importance.	Two activities contribute equally to the objective.
2	Weak or slight.	
3	Moderate importance.	Experience and judgement slightly favour one activity over another.
4	Moderate plus.	
5	Strong importance.	Experience and judgement strongly favour one activity over another.
6	Strong plus.	
7	Very strong or demonstrated Importance.	An activity is favoured very strongly over another; its dominance demonstrated in practice.
8	Very, very strong.	
9	Extreme importance.	The evidence favouring one activity over another is of the highest possible order of affirmation.

Source: Saaty (2008).

(4) To calculate the importance degree, the normalisation of the geometric mean method is used to determine the important degrees of the DMs requirements (Escobar et al. 2004). Let W_i denoted the importance degree (weight) for the i^{th} criteria, then:

$$W_i = \sqrt[n]{\prod_{j-1}^{n} a_{ij}} \Big/ \sum_{i=1}^{n} \sqrt[n]{\prod_{j-1}^{n} a_{ij}}\,,\ i,j = 1,2,\cdots,n\,, \tag{4.2}$$

where *n* is the number of criteria.

In addition, the maximum eigenvalue λ_{max} can be calculated by Equation (4.3) and Equation (4.4):

$$A^{*}w_i = \begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ 1/a_{12} & 1 & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ 1/a_{1n} & 1/a_{2n} & \cdots & 1 \end{bmatrix} * \begin{bmatrix} W_1 \\ W_2 \\ \vdots \\ W_n \end{bmatrix} = \begin{bmatrix} W_1' \\ W_2' \\ \vdots \\ W_n' \end{bmatrix}, \tag{4.3}$$

$$\lambda_{max} = (1/n) \times \left(W_1'/W_1 + W_2'/W_2 + \cdots + W_n'/W_n \right) . \tag{4.4}$$

(5) The next step is to test the matrix consistency through calculation, modifying it if necessary in order to get an acceptable consistency. In line with the premise of the consistency test, the eigenvector is calculated corresponding to the maximum eigenvalue λ_{max} of the pair-wise comparison matrix. The weight is then defined between each criterion and that in its upper level. The overall ranking weight between each criterion is then determined. The final step is to make the decision.

- Calculate CI (which stands for Consistency Index, λ_{max}) using the maximum eigenvalue of the pair-wise comparison matrix, *n* as the size of matrix:

$$CI = \lambda_{max} - n / n - 1 \,. \tag{4.5}$$

- In Equation (4.5), if $CI = 0,$ then the evaluation for the pair-wise comparison matrix is implied to be completely consistent. In particular, the closer the maximal eigenvalue is to *n*, then the more consistent the evaluation is found to be. Generally, a Consistency Ratio (CR) can be used as a guide to check for consistency (Saaty, 1996). Table 4.6 shows the order of the matrix and the average RI according to study of Aguarón and Moreno-Jiménez (2003), which is used to calculate Equation (4.6). The formulation for CR is:

$$CR = CI/RI. \tag{4.6}$$

If $CI < 0.1$, then the consistency of matrix is tolerant; otherwise the matrix should be modified.

Table 4.6: Average Random Index (*RI*) for corresponding matrix size

N	1	2	3	4	5	6	7	8	9	10	11	12
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48

Source: Saaty (1996)

4.4.3 ALTERNATIVE SCALES WITHIN AHP

The utilisation of alternative comparison scales within AHP is discussed in this section. As described above, a series of pair-wise comparisons and a unit scale are used in AHP to play a fundamental role in quantifying a DM's preference judgements. To date, the Saaty 1-9 scale is the 9-unit scale that has been most used in the AHP. Furthermore, some authors have tried to argue the appropriateness of the 1-9 scale, but the AHP literature has not addressed the answer as to which of the available alternative scales are most appropriate for the process of pair-wise comparisons. The influence of alternative scales on the results of the AHP analysis is assessed in this section.

As mentioned in the previous section, the pair-wise comparisons made are quantified by using numerical scale values, and they are processed in order to derive the final weight values ($Wi...Wn$). DMs are asked to compare two DAs at a time: 'Which one of these two DAs is preferred?' and 'How strongly is it preferred?' The DMs give weight ratios to indicate the strength of preferences by using linguistic terms, where the values of the pair-wise comparisons are determined according to the instructions depicted in the 1-9 scale (Saaty 1980). The importance of scales for preference elicitation has been emphasised by a number of previous practical works, and substantial empirical work is still required to characterise the specific strengths and weakness of scales (Hämäläinen and Salo 1997). Harker and Vargas (1987) stressed that the method of preference revelation that is used in this present study is entirely independent of the scale of measure. There have been several research studies that have suggested that the integers from one to nine (i.e. 1-9 scale) should be avoided when using AHP. Firstly, the 1-9 scale is a limited range of numbers that cannot correctly describe the preference ratios because of the weight of ratios that are above 9 (Harker and Vargas 1987; Schoner and Wedley 1989; Dyer 1990; Salo and Hämäläinen 1993; Pöyhönen et al. 1997).

Given that all methods are in some way scale dependent, there has been considerable discussion as to the correct scale to be used in the AHP and whether an unbounded scale should be used. Firstly, difficulty arises if Decision Alternative$_1$ (DA_1) is strongly preferred to DA_2 , and DA_2 is 'strongly preferred' to DA_3. The scale value in Table 4.5 for strongly preferred is 5. Therefore, to maintain consistency, it would have to be rated as $5\times5 = 25$ times preferred in comparison to DA_3. Hence, with a scale bounded by the largest value 9, this consistent judgement is not permitted.

Additionally, if the respondent evaluates a comparison that is beyond the boundaries of the scale, then the respondent is forced to modify the judgement and revise it so that it is within the upper and lower limits of the scale. Therefore, in order to represent the usual AHP relative comparisons, all pair-wise comparisons that exceed 9 are truncated to 9. In addition, in the AHP, the respondents are forced to provide integer numbers within a range of 1 to 9 although the actual judgement is not necessarily an integer. Consequently, all pair-wise comparisons are truncated to the nearest integer value (Carmone Jr. et al. 1997).

Thirdly, the 1-9 scale creates and deals with a very unbalanced scale of estimation. For matrices with reciprocal elements in the Saaty AHP, half of the non-diagonal elements are in the range of 1 to 9, and the other half are in the range of 1/9 to 1/1, which is smaller compared with the former (i.e. 1 to 9). In the reciprocals, the range is $1/1 - 1/9 = 0.889$, compared with $9 - 8 = 1$ in the integers (Ma and Zheng 1991; Mon et al. 1994; Triantaphyllou et al. 1994). Fourthly, although the use of the discrete scale of 1 to 9 has the advantage of simplicity, it does not take into account the uncertainty that is associated with the mapping of one's judgement onto a number (Brugha 2000; Leung and Cao 2000).

To overcome the deficiencies of the 1-9 scale, various judgement scales for a pair-wise comparison have been proposed and evaluated. Among these, Kok and Lootsma (1984) developed a geometric scale. A geometric scale quantifies the intensities of the preference based on psychophysical arguments (Saaty 1987). The geometric scale has been advocated over the Saaty 1-9 scale because of its transitivity and larger value span found in many situations, resulting in more robust selections (Legrady et al. 1984). In addition, Lootsma (1989) used a class of ratio scales based on a geometric progression. Ma and Zheng (1991) considered the 1-9 scale in relation to its representation of language, stating that the suitability of a scale should be measured by the consistency between the scale and the language. Therefore, they suggested that scales could have their values evenly distributed in the interval [1/9, 1], while the values in the interval [1, 9] could be simply the reciprocals of the values in the interval [1/9, 1].

Donegan et al. (1992) suggested the use of a scale that is partly linear and partly harmonic (∅ mapping scale), which resolves the unmathematical nature of the 1-9 scale. An evaluation of 78 different scales appears in a study by Triantaphyllou et al. (1994), which reveals that there is no single scale that can outperform all the other scales. Furthermore, the same findings indicated that a few scales are very efficient under certain conditions. Therefore, an appropriate scale for a successful application of pair-wise comparisons needs to be selected. Beynon (2002) suggested that the original 1-9 scale is ineffective, pointing out that alternative scales offer a good opportunity to follow linguistic scales, such as the 10/10 to 18/2 and 9/9 to 9/1 (Ma and Zheng 1991), ∅ mapping (Donegan et al. 1992) and 1.1 to 1.9 (Saaty 1987) scales.

Some related work has been carried out with verbal probability assessments where the verbal expression seems to be best modelled by interval judgement rather than point estimates (Beyth-Marom 1982; Hamm 1991; Timmermanns 1994). Hershey et al. (1982) showed that a linear transformation of an interval scale can drastically alter the results. Therefore, provided that these results can be generalised to ratio comparisons of relative preference, it is possible that exact numbers in the AHP should be replaced by intervals of numbers (Pöyhönen et al. 1997). Saaty and Vargas (1987) proposed an interval judgement for the AHP as a way to model the subjective uncertainty in the DM’s preferences. Meanwhile, Arbel (1989) developed efficient algorithms for synthesising interval judgements into dominance relations on the DAs.

Previous studies have revealed some of the limitations of the use of a 1 to 9 scale. Consequently, in this research, the 1 to 9 scale is contrasted with alternative scales. The alternative scales that are used in this study are illustrated in the following section.

4.4.4 THE FEATURES OF ALTERNATIVE SCALES

As shown in Table 4.7, the alternative scales that are considered in this section, apart from the original 1 to 9 scale, include two geometric scales, two scales from Ma and Zheng (1991) and the $\emptyset$ mapping scale (Donegan et al. 1992). There are also other scales which are numerically close to these five alternative scales but which have different theoretical motivations (Lootsma 1989).

In Table 4.7, the first column lists the verbal statements of preference taken from Saaty (1980). The second column is the 1-9 scale that was proposed by Saaty (1980). The third and fourth columns are geometric scales based on series of powers of 'e' and '2' (the e^{1-9} scale and the 2^{1-9} scale), which were applied by Legrady et al. (1984), who suggested that a geometric scale with powers of a suitable base number was more appropriate. Moreover, scaling of words and phrases expressing grades of approval or disapproval has shown that the response range (i.e. the ratio of the extreme stimuli) can easily be calculated up to 100; however, the 1-9 scale allows a response range of 9 only.

Table 4.7: Definition of alternative scales

Verbal statement of importance	Scale					
	1-9	e^{1-9}	2^{1-9}	9/9-9/1	10/10-18/2	ø mapping
Equal	1	e^{0}=1.0000	2^{0}=1	9/9=1.0000	1=1.0000	1.0000
-	2	$e^{0.5}$ =1.6487	2^{1}=2	9/8=1.1250	11/9=1.2222	1.1180
Moderate	3	$e^{1.0}$=2.7183	2^{2}=4	9/7=1.2857	3/2=1.50000	1.2536
-	4	$e^{1.5}$=4.4817	2^{3}=8	9/6=1.5000	13/7=1.8571	1.4142
Strong	5	$e^{2.0}$=7.3891	2^{4}=16	9/5=1.8000	7/3=2.3333	1.6125
-	6	$e^{2.5}$=12.1825	2^{5}=32	9/4=2.2500	3=3.0000	1.8708
Very strong	7	$e^{3.0}$=20.0855	2^{6}=64	9/3=3.0000	4=4.0000	2.2361
-	8	$e^{3.5}$=33.1155	2^{7}=128	9/2=4.5000	17/3=5.6667	2.8284
Extreme	9	$e^{4.0}$=54.5982	2^{8}=256	9/1=9.0000	9=9.0000	4.1231

Source: Organised by author.

The fifth and the sixth columns in Table 4.7 report the two 9-unit scales from Ma and Zheng (1991), namely $9/(10-k)$, and $(9+k)/(11-k)$ with $k=1,\cdots,9$ called '9/9 to 9/1' and '10/10 to 18/2' scales, respectively. The sixth column is also called a balanced scale (Salo and Hamalainen 1997), which is based on the idea that the local weights should be evenly dispersed over the weight range [0.1, 0.9] (Pöyhönen et al. 1997). The seventh column is a set of scale values that was introduced in Donegan et al.'s (1992) $\emptyset$ mapping scale. They use the formula "$\emptyset: t \rightarrow \exp\,(tanh^{-1}(\frac{t-1}{9}))$" to map into a range where "real" arithmetic applies (i.e. into a true ratio scale so that the transformation of the pair-wise comparison values can be used as entries to a comparison matrix which can then be handled in the usual AHP fashion). In this research, the weights of each variable using these six alternative scales are compared in the next chapter.

4.5 DATA ENVELOPMENT ANALYSIS (DEA)

This section aims to describe the DEA method, including its characteristics, the models which are employed in the research, and the progress of its evaluation.

The DEA method was first proposed by Charnes et al. (1978); they described the DEA methodology as

'a mathematical programming model applied to observed data that provides a new way of obtaining empirical estimates of external relationships such as the production functions and/or efficiency production possibility surfaces that are the cornerstones of modern economics.'

Since then, numerous applications employing the DEA methodology have been presented and involve a wide area of contexts: education, health care, banking, armed forces, sports, transportation, agriculture, retail stores and electricity suppliers (Gattoufi et al. 2004). Originally, this method was designed to evaluate the efficiency of DMUs, which use multiple inputs to produce multiple outputs, without a clear identification of the relation between them. DEA has progressed throughout a variety of formulations and uses in other kind of industries. Gattoufi et al. (2004) cited more than 500 articles in a comprehensive bibliography and stated that DEA methodology is an important analytical tool whose acceptance is no longer in doubt.

This research does not intend to cover the basic aspects of DEA models. A good introduction to DEA notation, formulation and geometric interpretation can be found in Charnes et al. (1994), Ali and Seiford (1993) and Coelli et al. (2005). As discussed therein, a model can be described by the envelopment surface, orientation of the model, invariance of units, and efficiency measurement.

The DEA method was first proposed by Charnes et al. (1978), who employed a mathematical programming model called the Charnes, Cooper, and Rhodes model (the CCR model) to measure the technical efficiency of DMUs using the Pareto optimum concept. Charnes et al. (1978) assumed that a situation involved Constant Return to Scales (CRS); namely, that increasing the input of a part would simultaneously increase the output. The problem with calculating DEA scores can, therefore, be viewed as a linear programming issue. The CCR model is usually applied in the first stage of DEA. It is also the first step in entering the DEA field. The CCR model includes both input and output-oriented models. This model is basically assumed to have constant returns to scale; however, each DMU might operate on different returns to scale, which may cause inefficiency.

Banker et al. (1984) extended the CCR model, which they termed the Banker, Charnes, and Cooper model (the BCC model). The BCC model assumes the existence of Variable Returns to Scale (VRS). The key part of these two models (i.e. the CCR and BCC) is that Charnes et al. (1978) included Pareto optimality into the model, in which each DMU selects the optimum input and output multiplier for the purpose of maximising its own efficiency, and the only constraint is that the value of the selected multipliers must not exceed 1 to satisfy the constraint that the maximum efficiency value is 1.

The choice of a DEA model depends on some assumptions regarding the data set to be employed and on some prior results about the industry to be studied. The data set has to describe the activities of the units in the best possible way. It is especially important to have some idea about the hypothetical returns to scale that exist in the industry. This knowledge is going to determine the envelopment CRS or VRS of the model. Once the selection of envelopment surface has been made, an orientation of the model to determine the measurement of the efficiency is needed. There are three basic orientations: input, output and output/input. An input orientation focuses on the proportional decrease of the input vector; the output orientation adjusts the proportional increase of the output vector, and the output/input orientation does not discriminate the importance of possible increases in output or decreases in input.

The units involved in this research determine the selection of the orientation, and it is very important to have in mind what the real possibilities of managers are. In the structure conduct-results tradition, the investigator must try to establish what the conduct of agents and the structure of the market are in order to determine a possible orientation for the model. In DEA analysis, it is generally assumed that there are n production units to be evaluated, using amounts of m different inputs to produce quantities of s different outputs. Specifically, the o^{th} production unit consumes x_{io} units of input i ($i = 1$ to m) and produces y_{ro} units of output r ($r = 1$ to s). The o^{th} production unit can now be described more compactly with the vectors (X_o , Y_o), which denote, respectively, the vectors of input and output values for DMU_o.

Next, we consider the dominance comparisons for this production unit using the data set as a reference. DEA considers the dominance of the linear combinations of the n production units, i.e. $(\sum k\ \lambda_k X_k, \sum k\ \lambda_k Y_k)$, with the scalar restricted to be non-negative. The production unit o is dominated, in terms of inputs, if at least one linear combination of production units shows that some input can be decreased without worsening the rest of the inputs and outputs. The production unit o is dominated in terms of outputs if at least one linear combination of production units shows that some output can be increased without worsening the rest of the inputs and outputs. Thus, the method serves to partition a set of production units into two subsets: the efficient production units and the inefficient ones. The method also serves to calculate the level of inefficiency of a given inefficient production unit. Airport managers can affect the efficiency of the airport using their inputs (such as runways, terminal buildings, employees, etc.) in different manners. In this research, an output orientation is employed. Once an airport has invested in the building of new runways or new terminals, it is difficult for managers to disinvest to save costs, therefore invalidating the input orientation (Martin and Roman 2001).

In this sense, it is more credible to use airport facilities as intensively as possible since variables of production are fixed or semi-fixed. Formally, the DEA output efficiency for the unit *o* is calculated through the following linear programming Equation (4.7):

$$\max_{\phi,\ \lambda, s^+ s^-} z_0 = \phi + (\varepsilon \times 1 s^+) + (\varepsilon \times 1 s^-) \tag{4.7}$$

$$\begin{aligned} \text{Subject to: } & Y\lambda - s^+ = \phi Y_o, \\ & X\lambda + s^- = X_o, \\ & 1\lambda = 1 \\ & \lambda,\ s^+,\ s^- \geq 0, \end{aligned}$$

where X and Y are the input and output matrixes, respectively; X_o and Y_o are the input and output vectors of the unit o, respectively; ϕ and λ are parameters calculated in the model, and represent the maximum proportional output that can be attained and the linear convex combination that dominates the o^{th} unit, respectively; ε and $s^+,\ s^-$ are the Archimedean constant and the slack variables, respectively.

The model compares the production unit *o* with all the convex linear combinations of production units. The linear programming problem is solved for every airport in the sample in order to obtain its relative performance. The efficiency measure obtained is considered the technical efficiency and is calculated as the inverse of the maximum proportional output that can be obtained for the indicated inputs.

4.6 LITERATURE OF INTEGRATED AHP/DEA MODEL

Although the combined AHP and DEA approach has attracted comparatively less attention (Ho 2008), an integrated AHP/DEA model has been developed and used for a number of purposes, including: supply chain performance evaluation (Guo et al. 2006), facility layout design in manufacturing systems (Yang and Kuo 2003; Ertay et al. 2006), warehouse operator selection (Korpela et al. 2007), improvement and optimisation of railway systems (Azadeh et al. 2007), and bridge risk assessment (Wang et al. 2008).

Ho (2008) has done an extensive review of integrated AHP and its applications, and has reported that only four papers have employed combined AHP and DEA. In addition to these papers, the combined AHP/DEA approach has been used in a number of different ways (Lozano and Villa 2007; Ramanathan 2006; Jing-Yuan et al. 2006). For example, Chen and Chen (2007) used DEA with a Balanced Scorecard (BSC) performance evaluation in the semiconductor industry, where they used AHP to obtain the weights for the four perspectives given by the BSC although in a research and development context, the application of an integrated AHP/DEA model has not yet been used and it has not been reported in the literature. Hsu (2005) used Fuzzy DEA with BSC for multinational research and development project performance assessment. While the DEA was originally designed for classification, it has been widely used to measure overall relative productivity and efficiency in relation to allocation decisions. The following paragraphs describe the characteristics and differences of the AHP/DEA approaches that have been developed in previous literature.

Xing and Tseng (2002) argued that the coefficient from the DEA model could be replaced with the weight from the AHP. To do this, the variable weight must first be determined. The efficiency of DMUs can then be obtained. However, the need to simultaneously obtain weight and efficiency makes achieving this difficult. On the other hand, in support of the integration of AHP and DEA, Sinuany-Stern et al. (2000) indicated that the AHP and DEA have the same characteristics for cases of single input and output. The basic idea is to employ a cross-evolution concept of AHP for ranking DEA DMUs and then to extend this to multiple inputs and outputs based on the DEA (Lee and Tseng 2006).

Takamura and Tone (2003) developed a combined AHP and DEA approach to deal with the relocation of several government agencies out of Tokyo. Firstly, the AHP was used to obtain the relative importance weightings of both criteria and attributes. Secondly, based on the AHP weightings, DEA was adopted to measure the effectiveness of alternative locations. Meanwhile, Yang and Kuo (2003) proposed a combined AHP and DEA approach to solve a facility layout design problem. A computer-aided layout planning tool (called Spiral) was adopted to generate a number of alternative layouts in advance. The relative importance weightings of alternative layouts were obtained by using the AHP pair-wise comparison with respect to three qualitative factors: flexibility, accessibility, and maintenance. DEA was then used to solve the layout design problem by simultaneously considering both the qualitative and quantitative performance data leading to the identification of performance frontiers. Saen et al. (2005) proposed a combined AHP and DEA approach to measure the relative efficiency of slightly non-homogeneous DMUs. Due to the fact that some DMUs may lack one or more features (i.e. input and/or output), they used AHP to estimate the missing features so that they could build a DMU that was as close to reality as possible. To do this, two alternatives were compared with respect to the attribute of the higher levels, which were: the DMU which lacked the feature(s) and the series means of other DMUs. The data for the mean of other DMUs was obtained by taking the mean of each feature of all DMUs with the exception of the one that had a missing value. The data was assumed to be normally distributed. Meanwhile, Ertay et al. (2006) applied the combined AHP and DEA approach to aid in facility layout design; their approach was very similar to that presented in Yang and Kuo (2003). Firstly, a computer-aided layout planning tool (called VisFactory) was adopted to generate a number of alternative layout designs. Secondly, the AHP was used to obtain the relative with respect to two qualitative factors, which were flexibility and quality. Thirdly, the DEA was used to evaluate the designs by simultaneously considering both qualitative and quantitative data. The best design was then selected. In addition, the flow distance, adjacency, and shape ratio that were proposed by Yang and Kuo (2003) were considered, as were the material handling vehicle utilisation and material handling costs. Korpela et al. (2007) developed an approach to select a warehouse operator network by combining the AHP and DEA. The outcome of the AHP analysis was a preference priority for each alternative operator describing the expected performance level.

Additionally, Feng et al. (2004) combined AHP and DEA to measure the efficiency of university management activities. Their study demonstrates that one of the basic concepts of AHP is the importance of pair-wise comparison. To support this, several studies have indicated that AHP can be applied to form an AHP/DEA ranking model for the purpose of improving DEA usability (Feng et al. 2004; Friedman and Sinuany-Stern 1998; Lee and Tseng 2006; Sinuany-Stern et al. 2000). The advantage of the AHP/DEA ranking model is that the comparative weight (or importance) can be derived from inputs/outputs via an AHP pair-wise comparison (Lee and Tseng 2006; Sinuany-Stern et al. 2000). While most studies of the AHP/DEA model have focused on investigating the efficiency of DMUs, a method by which to structure the appropriate weight of the input/output variables when DMUs achieve maximum efficiency has been relatively less studied, and, therefore, this is one of the research motivations of the present study (see Research Question 2).

4.7 DATA COLLECTION METHOD

There are practical reasons for the intensive use of survey-based methods to collect data in air transport research. Firstly, they allow for the involvement of various functions or locations within a firm, which are a convenient for gathering data. Secondly, surveys allow the researcher to reach upper managerial and executive levels. Lastly, surveys can ensure anonymity, and their standardised wording can help to avoid drawbacks, such as interviewer bias (Wagner and Kemmerling 2010). The following section briefly outlines the data collection methods and questionnaire development that are employed in this research.

The research gaps revealed from the literature review in Chapter 2 (Section 2.5) indicated that existing research has generally involved the subjective selection of evaluation variables by the authors. This gap can be filled easily by adopting more objective methods when choosing evaluation variables, such as interviews. Therefore, in this research, the AHP method is used, which includes semi-structured and structured interviews surveys to be used to develop an AEES.

4.7.1 SEMI-STRUCTURED INTERVIEW

Interviews are generally believed to be an appropriate method for an exploratory study to find out what is happening and to seek new insights (Robson 2002; Saunders et al. 2007). While in unstructured interviews, there is no predetermined list of questions to work through, in semi-structured interviews, the researcher has a list of questions and themes to be covered although these may vary from case to case. This means that the researcher can omit some questions in particular interviews and may change the order of questions depending on the flow of the conversation (Saunders et al. 2007). This research employed a semi-structured interview because the situations which the interview aimed to explore were relatively constrained. In other words, the exploration has to be made within the research questions and the AEES this research was intended to develop. However, the numbers of questions were minimised in order to make the interview more flexible and less directive and to obtain deeper understanding of interviewees' perceptions. One of the main objectives of conducting interviews is to ensure the validity and the reliability of the variables of the evaluation system. To address subjectivity concerns, which is often one of the major criticisms faced by qualitative research, this study has applied the AHP method during the process of variable selection. The characteristics and application of the pilot semi-structured interviews are described in Table 4.8.

Table 4.8: The characteristics of semi-structured interviews

	Characteristics of Semi-Structured Interviews	Application in this Research
1.	A semi-structured interview may be used for an exploratory study in order to understand the causal relationship between variables (Copper and Schindler 1998).	The semi-structured interview in this research is used to help the researcher understand the relationship between the variables and airport efficiency.
2.	The researcher should have a list of themes and questions on the fairly specific topics to be covered. The researcher may omit some questions in particular interviews (Bryman and Bell 2007; Saunders et al. 2007).	If an interviewee is a manager in an airport, then the interview questions emphasised the financial and service variables of the airport. In this pilot study, the questions were spread into different perspectives because the interviewed expert is a researcher on airport efficiency.
3.	Additional questions may be required to explore research questions and objectives given the nature of events within particular organisations (Saunders et al. 2007).	When facing different interviewees, different questions will be asked to help researchers to comprehend or amend research questions and objectives. In this pilot study, the expert can give some suggestions for the research questions and other areas of this research.

Source: Organised by author.

The semi-structured interview scheme allowed for the addition of more questions and asking these questions differently depending on the responses from interviewees. The interviews were recorded by note-taking and recording and then transcribed for analysis. Sampling interviewees and analysis are addressed in Chapter 5. While ethical issues, such as anonymity and confidentiality, occur when collecting primary data rather than secondary, these issues are generally considered more significant when conducting qualitative research as this involves direct interaction with persons as compared to quantitative research. Ethical issues are also presented in the section addressing sampling issues.

Analysis the qualitative data requires a different approach from that used when analysing quantitative data. Bryman and Bell (2007) indicated that clear-cut rules about how qualitative data analysis should be carried out have not been developed because qualitative data takes the form of a large corpus of unstructured textual material. However the basic concept for qualitative data analysis is categorisation and characterisation (Saunders et al. 2009). Several of the aspects the interviewees described in the interviews can be sorted into various categories. In this research, interviewees were asked to help identify the categories of variables which are appropriate to this AEES and also were asked to help select appropriate variables. For this reason, the author attempted to develop a preliminary AEES. This categorisation is supported by existing literature (addressed in Chapter 2). However some categories can emerge from the feedback of interviewees. After finishing this semi-structured interview, a structured questionnaire was undertaken in the next step.

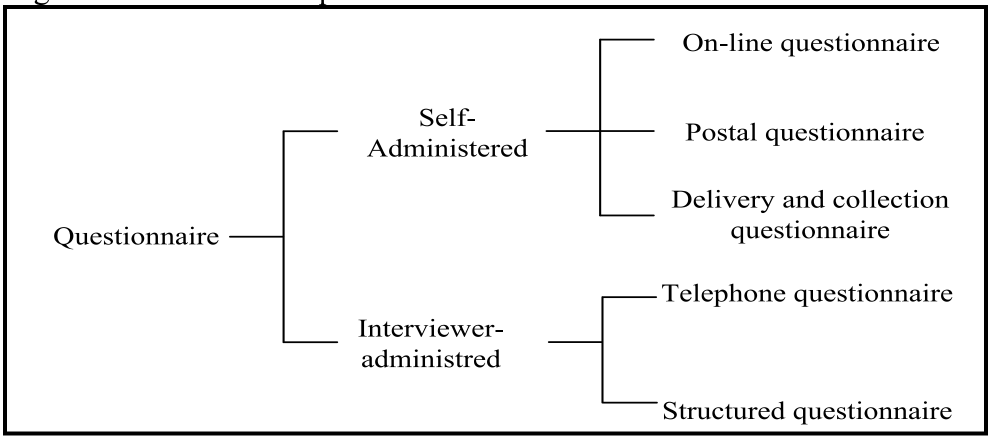
4.7.2 STRUCTURED INTERVIEW/ SURVEY

Structured interviews are often designed to emphasise the greater generality in the formulation of interviewer's concerns of the informants' perspectives (Bryman 2008). A structured interview can be conducted in a structured questionnaire. The advantage of structured interviews lies in the uniformity of the interviewees' behaviour; hence, other people than the researcher are able to replicate the interview in a similar situation (Ghauri and Grønhaug 2002). The formality of the answers comes in a uniform length which can lend itself nicely to being coded, quantified and compared (Denscombe 2003). In a normal structured interview, the limitation of sample size and analysis technique should follow some statistical order. In addition, unless there are some other reasons, the interviewees in structured interview are usually interviewed on one occasion only (Bryman 2008). The aim of a structured interview is to gather data from a statistically representative sample of the population in a controlled environment (Bryman 2008).

Due to the quantitative nature of the questions, a structured interview is designed to categorise, select and rank the appropriateness of variables that are adopted in an evaluation system. The interview questions intend to identify which variables are appropriate for use when evaluating airport financial and customer efficiency from each interviewee's point of view. In order to avoid any misunderstanding of the question, the researcher provides the definition of each variable in the questionnaire in order to increase both response and completion rates. The data from structured interviews can then be analysed through a quantitative approach to identify any significant differences between variables, such as through the use of ANOVA (Analysis of Variance) or other statistical methods. The results of the data analysis can help the researcher identify the most appropriate variables. In this research, the ANOVA method is not used to analyse the questionnaires, instead AHP analysis is used to analyse the questionnaire.

Because of the volume of respondents, visiting every prospective respondent would be difficult due to budgetary and time constraints. Therefore, in this research, a questionnaire survey was selected as the main empirical data collection method. According to Maylor and Blackmon (2005), a survey is a useful technique by which to capture facts, opinions, behaviour or attitudes from a range of respondents. However, according to Saunders et al. (2007), there are various types of survey methods that should be taken into account when implementing this specific method (see Figure 4.5).

Figure 4.5: Methods of questionnaire administration



Source: Saunders et al. (2007).

There are two main forms of questionnaires, namely: self-administered questionnaire sand interviewer-administered questionnaires. The main difference between these two forms is the involvement of an interviewer. Self-administered questionnaires are completed by the prospective respondent without any aid from the interviewer while interviewer-administered questionnaires require verbal or face-to-face contact between the interviewer and the interviewee (such as telephone questionnaires, structured face to face interviews, or questionnaires) (Maylor and Blackmon 2005). The interviewer-administrated questionnaire is one of the most common techniques that is used in all types of business and areas of management research (Maylor and Blackmon 2005; Aastrup and Halldorsson 2008). The flexibility of an interviewer-administrated questionnaire is that it focuses on a specific subject and the possible extension of its meaning. The interviewer-administrated questionnaire enables researchers to gain more freedom to probe beyond the answer through a form of dialogue with the respondent and, therefore, affords them the opportunity to collect additional information (May 2001; Bryman and Bell 2007). However, in large samples, this particular method is expensive in terms of time and cost, especially when the prospective respondents are geographically dispersed. Alternatively, a self-administered questionnaire method has more advantages in terms of convenience (i.e. time, cost, and location for both interviewer and interviewee); it is also less obstructive (i.e. absence of interviewer effects) to interviewers (Bryman and Bell 2007). There are a number of disadvantages which need to be considered when using self-administered questionnaires, such as lack of clarification when needed and less opportunity to collect additional data (Maylor and Blackmon 2005). In this research, some of experts are interviewed using a structured questionnaire.

Of the three self-administered methods, the postal questionnaire was adopted for use in this research, rather than an on-line questionnaire or a delivery and collect questionnaire. According to Bech and Kristensen (2009), among older respondents (i.e. those aged between 50 and 75) a postal or mail survey will have a typical response rate of around 30 % higher than an on-line survey. There are two main reasons why on-line surveys have a lower response rates than postal questionnaires including ‘survey fatigue’ or a lack of internet access on the part of the recipient. Due to the fact that the average ages of experts who were interviewed in this research were around 50, it was determined that the main questionnaire survey should be based on a postal questionnaire supported by a structured questionnaire.

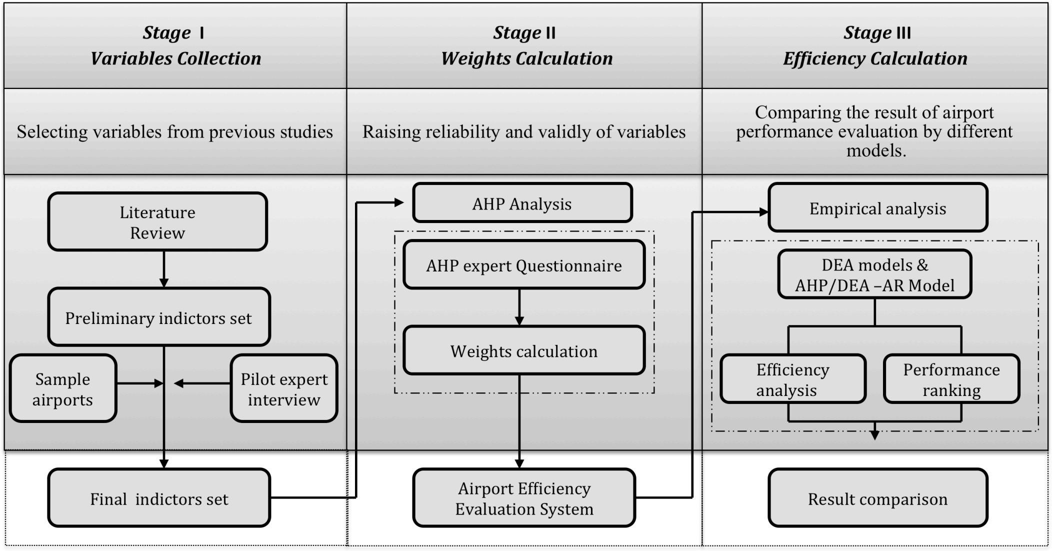
This study is aimed at the development of an AEES, and in order to enhance reliability and validity of the variables, the proposed approach employs two methods to select variables for the airport performance evaluation system. DEA is adopted to conduct quantitative analysis and the AHP method is employed to acquire the weight of individual variables. Therefore, two forms of data collection processes are used. The first is a semi-structured survey, and the second is a questionnaire survey. The former is intended to help the author conduct a pilot study that can acquire expert opinions to enable the establishment of evaluation variable sets that are obtained by means of in-depth interviews (semi-structured interviews). The latter are intended to obtain the weight of each variable resulting from handing out an AHP questionnaire (or by conducting so called structured interviews).

In addition, some secondary data, acquired from the Air Transport Research Society (ATRS) and the annual report from individual airports, are also used in this research when undertaking the DEA analysis.

4.8 RESEARCH STRUCTURE AND SURVEY DESIGN

After discussing several concepts on research design in the previous sections, the research process is described in this section. The framework of the research procedures that are used in this study and the tasks of each stage are summarised and presented in Figure 4.6.

Figure 4.6: Framework of research procedures



Source: Organised by author.

4.8.1 Stage I: Variables collection

A preliminary variable set is constructed in the first stage, which is based on the research presented in Chapter 2 (Section 2.3.4). In the preliminary variables set, seven inputs (i.e. number of employees, number of gates, number of runways, size of terminal area, length of runway, operational expenditures, and non-operational expenditures) and five output variables (i.e. number of passengers, amount of freight and mail, aircraft movements, aeronautical revenue, and non-aeronautical revenue) were chosen. These seven input and five output variables are selected from the most widely used variables among the 66 previous studies of airport efficiency (see Table 2.3 and Table 2.4).

Generally speaking, AHP is a method that uses both semi-structured interviews and structured interviews to acquire data. In this stage, a pilot study (semi-structured interview) is conducted after setting up the preliminary evaluation system in order to enhance the reliability and validity of the preliminary variables. One of the advantages of conducting a pilot study is that it can give advance warning about where the main research could fail, where the research protocols may not be followed, or whether the proposed methods or instruments are either inappropriate or too complicated (Polit et al. 2001). The suggestions that were made during the pilot study in this research came from three experts who were selected from different areas: academia, practice, and the airport authority. The accessibility of the airport data needed to be considered when deciding the final version of variable sets. The final variables were then set up after these semi-structured interviews were completed (further details on this stage are presented in Chapter 5).

The selection of the sample airports is another important task in this stage. There are two main principles for selection of the sample airports. One of the objectives of the research questions was to examine if airport ownership or governance have an influence on an airport performance. Therefore, the first principle for sample selection was that the samples should cover eight types of airport ownership, as put forward by Oum et al (2006) and Gillen (2011) and detailed in Section 3.3.1. However, one aspect of airport ownership, independent non-profit corporations, can only been found in Canada and is therefore outside of the geographical scope of this thesis. The second principle is that the sample airports should be similar in nature, as derived from the limitations of DEA. Therefore, in this research, the sample airports consisted only of primary airports in two regions (i.e. Europe and the Asia-Pacific region) due to the availability and accessibility of the data and the variety of airport ownerships. According to these two principles and the survey from “Air Traffic Data of 2010”, which is published by the Airport Council International (ACI), the sample size is limited to the busiest 12 airports from each region. Table 4.9 shows 24 sample airports which are studied in this research and the seven different types of airport ownership mentioned in Chapter 3 (see Section 3.1.3) are covered.

Table 4.9: Sample airports in this research

Europe	Ownership Category	Asia-Pacific	Ownership Category
Amsterdam (AMS)	Private company (Public majority)	Bangkok (BKK)	Private company
Barcelona (BCN)	Public-owned company	Beijing (PEK)	Private company
Frankfurt (FRA)	Private company (Public majority)	Guangzhou (CAN)	Private company
Istanbul (IST)	Public-owned, operated by a private company	Hong Kong (HKG)	Public-owned company
London (LGW)	Private company	Incheon (ICN)	Public-owned company
London (LHR)	Private company	Kuala Lumpur (KUL)	Public-owned company
Madrid (MAD)	Public-owned company	Osaka (KIX)	Private company (Public majority)
Munich (MUC)	Public-owned company	Tokyo (HRT)	Public-owned company
Paris (CDG)	Private company	Shanghai (PVG)	Public-owned company
Paris (ORY)	Private company	Singapore (SIN)	Public-owned
Rome (FCO)	Private company	Shenzhen (SZX)	Private company (Public majority)
Zurich (ZRH)	Private company	Sydney (SYD)	Private company

4.8.2 STAGE II: WEIGHTS CALCULATION

In this stage, the weights of each variable are developed using basic AHP 1-9 scales and other alternative scales. By making pair-wise comparisons at each level of the hierarchy, the participating experts can develop relative weights and set priorities. They can then differentiate the importance of the variables with continued feedback and revisions.

In this stage, an AHP questionnaire, which focuses on managers from airport companies, air transport researchers, or officers in civil aviation authorities, is carried out to determine what the most important variables for these interviewees are when evaluating airport operational efficiency. The final version of the selected variables is used to establish the AEES. Some of questionnaires were handed out by post and some of were conducted using face to face structured interviews (a copy of the questionnaire that was used is attached in Appendix II).

4.8.3 STAGE III: EFFICIENCY EVALUATION

The third stage of this research is aimed at applying variable sets to assess the efficiency of the sample airports. In general, the performance is evaluated in terms of relative efficiency by applying the basic DEA model and an integrated AHP/DEA model. Four main steps are followed in this stage; firstly, computing the relative scores of variables from raw data and analysing in different groups; secondly, computing the relative weighted scores of all individual airports based on weights which are derived from AHP analysis in alternative scales; thirdly, evaluating the efficiency in terms of the relative weighted score for each airport (in this step a DEA model is used to evaluate airport efficiency); and finally, measuring the operating efficiencies of primary airports in Europe and Asia-Pacific region by applying integrated AHP and DEA models. Identifying the benchmark airport and the relatively inefficient airports is the main task in this step. Additionally, comparison of airport performance using a set of standardised benchmarking and reporting variables benefits both airport managers and stakeholders who wish to make judgements about airport performance, both comparatively and individually. Furthermore, sensitivity analysis is also conducted in this research, and another variable set (six variables) and analysis techniques (AHP/DEA-AR model) are implemented in this stage.

4.9 SUMMARY

This chapter was devoted to the methodological issues of this thesis. Firstly, a general discussion of research philosophies, approaches and strategies was presented. This study is based on the positivist paradigm, and it recognises the airport industry as an objective and external entity. Consequently, this research applies a deductive approach and adopts surveys as a research strategy. It employs the quantifiable quantitative data analysis method (i.e. DEA models and the AHP/DEA model) to determine the relationship between airport privatisation policy and efficiency. Because a number of airports in different countries are selected as the sample in this research, a cross-sectional research design is employed to answer the research questions. To acquire the relative importance of each variable from experts in different areas, in-depth interviews (i.e. semi-structured interviews), structured questionnaires, and postal questionnaires are adopted by the researcher as data collection methods. The data analysis methods are also described. The reasons of using alternative scales are initially discussed. Secondly, the characteristics of AHP and the nature of alternative scales within AHP are outlined. Thirdly, the characteristics of DEA, the basic two DEA models are described. Finally, the framework of the research procedures and methods are presented.

CHAPTER 5

EMPIRICAL ANALYSIS:
AHP ANALYSIS

The last chapter provided an extensive explanation of the methodological tools and analysis methods employed in this research. The aim of this chapter is to present the findings of the AHP questionnaire. This chapter includes two main sections. The first section addresses the results of the pilot questionnaire that will be used to confirm the complete AEES which is going to be applied in this research. The second section presents an overview of the relative AHP weights of the variables and their classification into different groups. It then concludes with a brief summary of the analysis of this research.

5.1 PRELIMINARY EVALUATION VARIABLES

According to Figure 4.6, the preliminary variable set is going to be established in Stage I. From the literature review (Section 2.3.4), a range of input and output variables was suggested. A preliminary selection of nine input variables and five output variables was made (as shown in Table 5.1) by the author. The following principles have been taken into consideration when the variables were chosen:

- According to the assumption of DEA, the number of DMUs should be at least more than the product of the input and output variables (Charnes et al. 1985). Ali et al. (1987) and Bowlin (1987) advised that the number of DMUs should be at least twice the sum of the input and output variables.
- The variables in different hierarchies groups should not have more than seven variables (Saaty 1980).
- The selected variables must be comprehensive enough to provide an effective evaluation of the operational performance of international airports.
- As noted in Section 2.3.4, the selection of variables in the preliminary variable sets is based on the most widely used variables in the past 20 years (see Table 2.3 and Table 2.4).

The preliminary variables can be classified into two hierarchies, which include an input perspective (whose main-criteria consist of airport capacity and financial concerns) and an output perspective (whose main-criteria includes service performance and financial performance).

5.2 THE PILOT STUDY PROCESS

The aim of conducting pilot interviews is to ensure the validity and reliability of the preliminary variables. To address the concern of subjectivity, which is usually one of the major criticisms faced by research, the AHP method is used after the process of selecting the variables. Following the guidelines of the research framework (which was described in Section 4.8), three experts were invited to join individual semi-structured interviews. They were invited from academia, the airport authority (airport company), and the civil aviation authority (department of transport). Three of them have been involved in air transport relevant business or research for more than 20 years.

Table 5.1: The preliminary variables of airport efficiency evaluation system

Main criteria	Sub-criteria	Definition of the criteria
Input		
Airport capacity	Number of employees	The number of full-time equivalent employees directly employed by the airport.
	Number of gates	The number of gates with jet ways and other non jet-way gates.
	Number of runways	The available number of runways at each airport.
	Number of check-in desks	The number of the desks where passengers check in their bags and cases and have their tickets checked at an airport.
	Number of car parking spaces	The number of the spaces where people can park their cars in an airport.
	Size of terminal area	The total area of passenger terminals.
	Length of runway	The average runway length of every runway in each airport.
Airport finances	Non-Operational expenditure	The debt services, capital expenditure and other non-operating expenses.
	Operational expenditure	The financial resources needed to run an airport, including salaries and benefits, communications and utilities, supplies, materials, repairs and maintenance, services and other expenses.
Output		
Main criteria	Sub-criteria	Definition of the criteria
Service performance	Number of passengers	The number of passengers arriving or departing at an airport (including terminal passengers and transit passengers).
	Amount of freight and mail	The weight of property carried on an aircraft and the weight of Post Office mail carried.
	Aircraft movements	The number of landings or take-offs of aircraft engaged in the transport of passengers, cargo or mail on commercial terms.
Financial performance	Aeronautical revenues	The revenues that are generated by aviation activities such as landing fees, terminal fees, apron charges, fuel flowage, fixed base operators (FBOs), rentals and utilities.
	Non-aeronautical revenues	The rents, concessions, parking, rental cars, catering, etc.

Source: Organised by author.

5.2.1 QUESTIONS IN THE PILOT EXPERT INTERVIEW

A series of questions were asked in the expert pilot interview in order to understand the entire picture of the current airport industry. The expert questionnaire had three sections: firstly, some questions about the airport industry were asked; secondly, the experts were asked about some general ideas regarding an airport performance evaluation; finally, they were asked to help to select appropriate input and output variables.

The order of the interview questions is presented as follows:

1. **The current situation about airport industry:**
   a. *Do you think the airport industry is dramatically changing?*
   b. *Do you think the competition between airports has become more intensified?*
   c. *From your viewpoint, what strategy is the most useful to improve airport operational efficiency (e.g. Privatisation or Commercialization)?*

2. **The needs of the airport evaluation system:**
   a. *What are the key variables related to airport efficiency?*
   b. *Do you think every airport needs to measure performance regularly?*
   c. *Do you think every airport needs to develop its own evaluation system?*
   d. *From your viewpoint, which benchmarking technique is the most useful to evaluate airport operational efficiency?*

3. **The appropriateness of variables:**
   a. *Which variables are appropriate for measuring airport efficiency in each level? (Please provide your answer in the following table).*
   b. *Other suggestions about variables.*

5.2.2 INTERVIEW RESULT ANALYSIS

From pilot interviews, experts can help to amend variable sets. Based on these suggestions, the researcher can improve the evaluation system objectively.

- **Main-Criteria**

  All experts agreed that the author's classification of the main criteria into airport capacity and airport financial concerns from the input perspective and service performance and financial performance from the output perspective are suitable.

- **Sub-Criteria**

Based on the literature review, the preliminarily evaluation variables were selected by the author. There are nine variables in the input and five variables in the output. However, according to the limitations of the DEA, the number of DMUs and variables should be considered. In this study, 24 airports are selected as DMUs (see Section 4.8). As mentioned in Section 5.1, the number of DMUs should be at least greater than the product of the input and output variables or at least twice the sum of the input and output variables. Therefore, in this research, the appropriate number of variables should not exceed more than six variables in regard to two different perspectives in order to achieve the first requirement. Consequently, the number of variables must be reduced. The suggestions about variables in the sub-criteria are described as follows:

5.2.2.1 INPUT PERSPECTIVE

- **Airport Capacity**

All of the experts agreed that the number of employees, number of gates, number of runways, and length of runways are suitable for the AEES in this research. The number of employees can help researchers to understand how many employees are employed in different airports in order to provide similar services. The number of gates can help researchers to determine how many aircraft can be served at a specific time. The number of runways can assist researchers in determining how many aircraft movements can be handled during a specific period of time. The length of runways affects the ability to handle larger aircraft; in which case, the airport can serve more passengers.

Some experts did show their concern about particular variables. For example, only one expert thought that the number of check-in desks is appropriate for airport efficiency evaluation, while the other two experts suggested that the size of the terminal area is similar to this variable; therefore, the researcher only kept one of these two variables. None of the experts felt that the number of parking spaces is an important variable for airport evaluation efficiency. One of them suggested instead the addition of a variable about the number of public transportation routes.

- **Airport Finances**

  All of the experts agreed that this research should only include the variable of operational expenditure. This is considered to be appropriate because some airports (such as Amsterdam and Dubai) have recently tried to develop the concept of an "Airport City". Consequently, this new kind of airport may need to produce more expenditure related to non-operational expenditure, which is not related to airport operation.

5.2.2.2 OUTPUT PERSPECTIVE

- **Service performance**

  The author used three variables (i.e. number of passengers, amount of freight and mail, and aircraft movements) as sub-criteria when evaluating service performance. All of the experts felt that the philosophy of a business operation is to learn how to acquire maximum benefit by applying limited resources. Consequently, these three variables can help the researcher to determine the efficiency of an airport. Therefore, these three variables are all suitable.

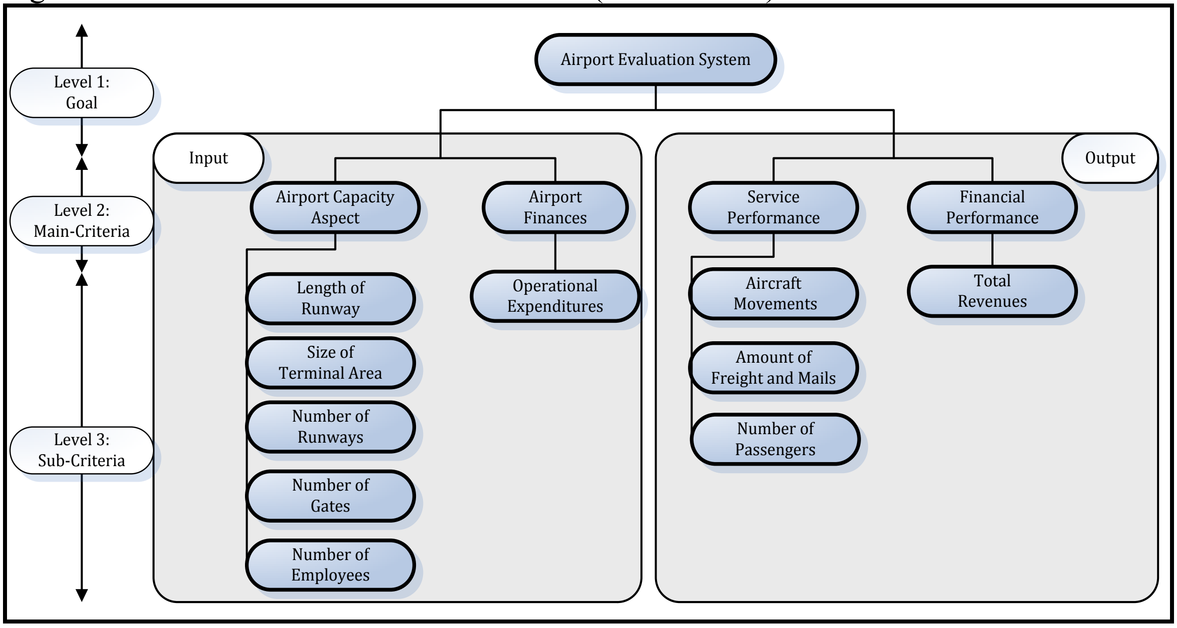
- **Financial performance**

  Currently, non-aeronautical revenue is becoming more important for every airport. Therefore, all of the experts suggested that total revenue is appropriate when evaluating airport efficiency.

After the interviews, the experts provided some suggestions to help the researcher to improve the AEES with reliable and objective variables. Eventually, ten variables were selected, in input perspective, airport capacity and financial considerations were kept as the main criteria. Among the sub-criteria, six variables were selected. The number of car parking spaces, the number of check-in desks, and the non-operational expenditure were removed because they are less relevant or have similar definitions to those of other variables.

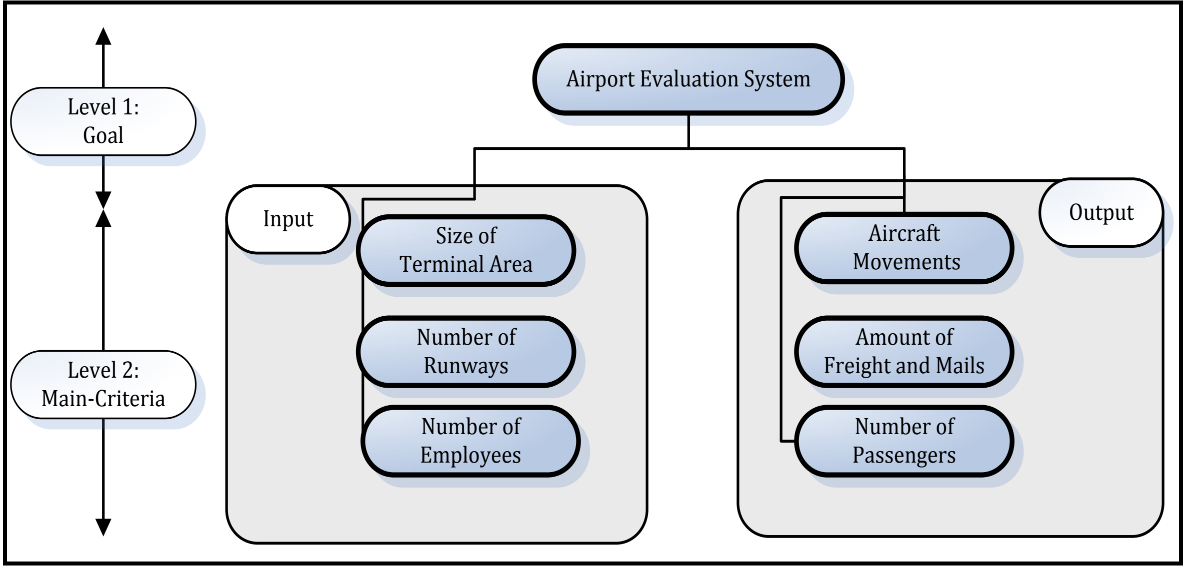
From the output perspective, the main criteria of service performance and financial performance were kept. Regarding, the sub-criteria, all of variables were reserved because of less relevance, aside from non-aeronautical revenue. The new set of ten variables is illustrated in Figure 5.1. However, in order to conduct sensitivity analysis and answer Research Question 4: Does the number of input and output variables affect the results for airport efficiency?, another variable set was also employed in this research. In this variable set, only two hierarchies and six variables were chosen (the details are shown in Figure 5.2). The variable selection in this set is also based on the most widely used variables in the past 20 years and suggestions from experts (see Section 2.4).

Figure 5.1: AHP hierarchies of Variable Set I (ten variables)



Source: Organised by author.

Figure 5.2: AHP hierarchies of Variable Set II (six variables)



Source: Organised by author.

5.3 RELATIVE IMPORTANCE EVALUATION OF VARIABLES

After constructing an AHP hierarchy of airport efficiency evaluation, in stage II, a structured interview and postal survey (AHP questionnaire) were applied in order to explore the weights and priority analysis of each variable. A questionnaire entitled "Airport Efficiency Evaluation Questionnaire" was devised based on the hierarchy shown in Table 5.1. This questionnaire was designed in terms of AHP, a principle that makes pair-wise comparisons at the same level. The measurements were made on a scale from 1 to 9. The definition of each scale is shown in Table 4.5, and the actual questionnaire is attached in Appendix II. Between both variable sets, only one variable (i.e. total revenue) is different in regard to the output perspective. Therefore, when designing the questionnaire for the VSII, the author only needed take the main criteria of financial performance into consideration. The interviews did not have to address the relative importance of aircraft movement, amount of freight and mail, and number of passengers. In the meantime, the relative weights can be introduced from VSI.

In stage II, the data collection was comprised of gathering responses from 36 airport management specialists in two distinct categories: In practice, questionnaires were posted to 24 sample airport companies or authorities. In the area of academia, 11 scholars in related fields such as those in charge of airport management or transportation management were selected from North America, Asia, and Europe, as selected from an ATRS experts list.

All respondents were given clear instructions prior to filling out the questionnaire. The survey was carried out in two rounds. The first round was from 2011/03/01 to 2011/03/15; the second round was from 2011/04/01 to 2011/04/15. Details about the respondents and the response rate are displayed in Table 5.2. There were a total of 35 questionnaires sent out, and 25 questionnaires were collected, giving a response rate of 71.43%.

The weights of each variable were calculated using the answers of the respondents and were calculated using Super Decision (an AHP software program) and cross checked using equations programmed with Maple. If the Consistency Index (*CI*) was < 0.1, then the consistency in the respondent's questionnaire was considered to be acceptable;

otherwise, the questionnaire has to be returned for re-answering or should be excluded from effective responses, which explains the reliability of the weight. In this research, the effective rate was 62.86%, which was achieved for 22 acceptable questionnaires (as shown in Table 5.2). When using Super Decision, the geometric mean method for solving the eigenvalue of the pair-wise comparison matrix was used to calculate the local weight of each level using a spread sheet (Saaty 2003).

Table 5.2: Effectiveness of questionnaires

	Region	Sent out	Copies of return	Response rate	Copies of effectiveness	Rate of effectiveness
Academia	North America	3	2	66.67%	2	66.67%
	Asia	4	4	100.00%	4	100.00%
	Europe	4	2	50.00%	1	25.00%
	Sub-total	11	8	72.73%	7	63.64%
Practice	EU	12	8	66.67%	7	58.33%
	Asia	12	9	75.00%	8	66.67%
	Sub-total	24	17	70.83%	15	62.5%
Total		35	25	71.43%	22	62.86%

Source: organised by author.

5.3.1 THE WEIGHTS ANALYSIS OF VARIABLE SET I (VS I): MAIN-CRITERIA

Table 5.3 introduces the pair-wise comparative matrix for the hierarchy that is concerned with comparing the relative importance matrix of airport capacity and airport finances. After calculating the geometric mean of 22 questionnaires, among these two criteria, all the experts felt that airport finances are more important than airport capacity. On the left side of Table 5.3, the results show the weight of airport capacity to be 0.3759 and the weight of airport finances to be 0.6241 (the calculations are shown in Section 4.4).

This means that among these 22 experts, when evaluating airport efficiency, they felt the importance of airport capacity to be less than airport financial concerns. In addition, the *CI* and the *CR* in this comparison matrix were all equal to 0 and smaller than 0.1; therefore, the results are considered to be reliable.

Table 5.3: Pair-wise comparison matrix and weights for level 2

Input				Output			
Main criteria	Airport capacity	Airport finances	**Weights**	Main criteria	Service performance	Financial performance	**Weights**
Airport capacity	1	0.6022	**0.3759**	Service performance	1	1.0019	**0.5005**
Airport fiance	1.6605	1	**0.6241**	Financial performance	0.9981	1	**0.4995**
$CI = 0 < 0.1; CR = 0 < 0.1$				$CI = 0 < 0.1; CR = 0 < 0.1$			

Table 5.4 shows how the results of the main criteria can be broken down into three different groups: experts from academia, practice, and overall experts. On the input side, all of the experts from these two groups felt airport finances to be more important than airport capacity, and the experts from practice were more concerned about this topic (i.e. 64.5% and 52.45%). There was a difference of opinion on the output side. The experts from academia argued that service performance in an airport should be emphasised more than financial performance when evaluating airport efficiency; however, the airport managers were found to place more emphasis upon financial output than the academic researchers, probably because airport managers have a responsibility to the stakeholders (although they still take service output into account).

Table 5.4: Local weights in level two in different groups

	Input		Output	
	Airport capacity	Airport finances	Service performance	Financial performance
Practice	0.3549	**0.6450**	0.4133	**0.5867**
Academia	0.4755	**0.5245**	**0.7349**	0.2561
Overall	0.3759	**0.6241**	**0.5005**	0.4995

5.3.2 THE WEIGHTS ANALYSIS OF VS I: SUB-CRITERIA

5.3.2.1 INPUT PERSPECTIVE

The variables under airport capacity indicate the resources inputted by the airport authority. Five variables were selected for this variable (i.e. number of employees, number of gates, number of runways, size of terminal area, and length of runway). Table 5.5 shows the weights of these sub-criteria. Among the five variables in this area, the experts felt the number of gates to be the most important variable, followed by size of terminal area and number of runways. The range between these two variables was less than 0.03 (i.e. 0.1173 and 0.0946). There was less importance gap among other variables but only number of employees. The *CI* = 0.0137 and *CR* = 0.0122 were both smaller than 0.1; therefore, the results in this comparison matrix are reliable. Among these input variables, operating expenditure was found to be the most important variable (0.6241).

Table 5.5: Pair-wise comparison matrix and weights for level 3

Sub-criteria	(A1)	(A2)	(A3)	(A4)	(A5)	Local Weights	With Respect to Airport Capacity Variables
(A1) Number of employees	1	0.2731	0.2140	0.2560	0.3257	0.0606	0.0228
(A2) Number of gates	3.6619	1	1.5640	1.4509	2.2048	**0.3122**	**0.1173**
(A3) Number of runways	4.6721	0.6394	1	0.8472	1.6301	0.2299	0.0864
(A4) Size of terminal area	3.0699	0.6892	1.1804	1	2.0497	0.2516	0.0946
(A5) Length of runway	3.0699	0.4535	0.6134	0.4879	1	0.1457	0.0547
(B1) Operating Expenditure	-	-	-	-	-	0.6241	0.6241

$CI = 0.0137 < 0.1; CR = 0.0122 < 0.1$

Table 5.6 shows that the experts in academia felt the size of the terminal area to be the most important variable in regard to airport capacity, followed by the number of gates and number of runways. However, the experts selected from practice felt the number of gates to be the most of essential variable in regard to airport capacity, followed by size of the terminal area and number of runways.

The possible reason why the experts from academia emphasise this variable more than others is that they might be concerned about the feelings of the passengers (basically, they believe that the main aim of an airport is to satisfy passengers). On the other hand, the experts from practice felt the number of gates to be the most important variable for an airport because the airport authorities think that more gates means that they can serve more aircraft. However, the gaps between the second and third-ranked variables in the two different groups were only slightly different. Nevertheless, experts from these two groups placed less emphasis on the influence of employee numbers on airport efficiency. Among these input variables, the experts felt operating expenditure to be the most important variable not only in academia but also in practice.

Table 5.6: Local weights in level 3 in different groups

	(A1) Number of employees	(A2) Number of gates	(A3) Number of runways	(A4) Size of terminal area	(A5) Length of runway	(B1) Operating expenditure
Practice	0.0576	**0.3336**	0.2239	0.2354	0.1495	0.6450
Academia	0.0586	0.2660	0.2153	**0.3233**	0.1368	0.5245
Overall	0.0606	**0.3122**	0.2299	0.2516	0.1457	0.6241

5.3.2.2 OUTPUT PERSPECTIVE

The variables in service performance indicate how many entities (i.e. passengers, aircrafts, and cargo and mail) can be served by an airport. In this aspect, three variables were selected: number of passengers, amount of freight and mail, and aircraft movements. Table 5.7 shows the weights of these three variables as they were awarded by the experts when considering output in an airport. The number of passengers was deemed the most important variable, followed by the amount of freight and mail and aircraft movements, because the main concept of an airport is to transport passengers and freight. In addition, the range between the first and the other two ranked variables was quite significant. The CI = 0.0055 and CR = 0.0095, both were smaller than 0.1, indicating the results to be reliable. Among these output variables, total revenue was found to be the most important variable (0.4995).

Table 5.8 shows that all of the experts in these two group agreed that when reviewing an airport output, the number of passengers is the most essential variable, followed by the amount of freight and mail and aircraft movements. The importance of the number of passenger was found to be much higher than that of the other variables.

Table 5.7: Pair-wise comparison matrix and weights for level 3

Sub-Criteria	(C1)	(C2)	(C3)	Local Weights	With Respect to Service Performance
(C1) Number of passengers	1	1.7045	3.2193	**0.5206**	**0.2605**
(C2) Amount of freight and mail	0.5867	1	2.3735	0.3296	0.1649
(C3) Aircraft movements	0.3106	0.4213	1	0.1498	0.1498
(D1) Total revenue	-	-	-	0.4995	0.4995

$CI = 0.0055 < 0.1; CR = 0.0095 < 0.1$

Table 5.8: Local weights in level 3 in different groups

	(C1) Number of Passengers	(C2) Amount of Freight and Mail	(C3) Aircraft Movements
Practice	**0.5389**	0.3232	0.1379
Academia	**0.4715**	0.3801	0.1480
Overall	**0.5206**	0.3296	0.1498

5.3.3 WEIGHT ANALYSIS OF VARIABLE SET II (VS II): MAIN-CRITERIA

In order to conduct sensitivity analysis in this research, VS II (six variables) were adopted to calculate the weight of each variable.

5.3.3.1 INPUT PERSPECTIVE

In this variable set, three input variables were selected: number of employees, number of runways, and size of terminal area. Among these input variables, experts felt the size of the terminal area to be the most important variable, followed by the number of runways and number of employees. From Table 5.9, it can be seen that the importance of the number of employees is much lower than that for the other two variables. In comparison with VS I, the number of employees is once again the less important variable in the input aspect. The CI = 0.0126 and CR = 0.0217 are both smaller than 0.1.

Table 5.9: Pair-wise comparison matrix and weights in input aspect

Criteria		(A1)	(A2)	(A3)	Local Weights
(A1)	Number of employees	1	0.2140	0.2560	0.1047
(A2)	Number of runways	4.6721	1	0.8472	0.4362
(A3)	Size of terminal area	4.6721	3.9066	1	**0.4590**

$CI = 0.0126 < 0.1; CR = 0.0217 < 0.1$

The results from Table 5.10 can be analysed in three groups. The experts from academia felt the size of the terminal area to be the most important input variable, followed by the number of runways and number of employees. However, the experts from practice felt the number of runways to be the most essential input variable, followed by the size of terminal area and number of employees. The overall ranking of these variables were the same as VS I (Table 5.5). The difference between the first and second ranked variables was only slightly different. Nevertheless, all of the experts from these two different groups believed that the number of employees does not significantly influence airport efficiency.

Table 5.10: Weights in different groups

	(A1) Number of Employees	(A2) Number of Runways	(A3) Size of Terminal Area
Practice	0.1035	**0.4505**	0.4459
Academia	0.1071	0.4059	**0.4870**
Overall	0.1047	0.4362	**0.4590**

5.3.3.2 OUTPUT PERSPECTIVE

In this variable set, three output variables were selected: number of passengers, amount of freight and mail, and aircraft movements. These three variables were the same as the variables in the service performance area of VSI. In VSII, financial performance was not taken into consideration. Therefore, there was no need to ask experts to answer another AHP questionnaire survey among these three variables. The relative weights of these three variables are shown in Table 5.7. The results from Table 5.8 are also presented there. All of the experts from these two groups agreed that the variable of aircraft movements is less important for airport efficiency.

5.4 OVERALL WEIGHTS OF AIRPORT PERFORMANCE EVALUATION

The overall weights of each variable determine their integral priority with respect to airport efficiency as a whole, which can be calculated from the local weight of each aspect and their variables using the weighting method and the AHP approach assumption.

These weights additionally enable policy makers to have a more detailed understanding of the relative importance among these variables in the situation as a whole, and the overall weights can also serve as an important reference when they make a decision on the priorities for strategy formulation and when they decide on action items when there are multiple goals to be considered with limited resources. In this research, these weights are conducted using DEA analysis. By means of this, an objective AEES can be established, and a more accurate airport efficiency result can be found.

5.4.1 OVERALL WEIGHTS OF VS I

The overall weights of the VS I are shown in Table 5.11. Among these variables, the input side operational expenditure, which belongs to the financial area, is the highest overall weighted variable. This indicates that operational expenditure should be taken into consideration in the first place for airport efficiency evaluation. The second overall weighted variable is the number of gates, and the third weighted variable is the size of the terminal area, which suggests that when evaluating airport efficiency, these two variables should be considered over others in regard to airport capacity.

On the output side, total revenue, which belongs to the area of financial performance, is the highest overall weighted variable. This indicates that total revenues should first be taken into consideration on the output side for airport efficiency evaluation. The second overall weighted variable is the number of passengers, and the third weighted variable is the amount of freight and mail. This suggests that when evaluating an airport, the airport authority should consider these two highest variables first.

Table 5.11: Weights of airport efficiency evaluation system (VS I)

Input					
Main-Criteria	Weights	Sub-Criteria		Local weights	Overall weights
Airport capacity	0.3759	(A1)	Number of employees	0.0607	0.0228 (6)
		(A2)	**Number of gates**	**0.3122**	**0.1173 (2)**
		(A3)	Number of runways	0.2299	0.0864 (4)
		(A4)	Size of terminal area	0.2516	0.0946 (3)
		(A5)	Length of runway	0.1457	0.0547 (5)
Airport finance	**0.6241**	**(B1)**	**Operational expenditure**	**0.6241**	**0.6241 (1)**
Output					
Main-Criteria	Weights	Sub-Criteria		Local weights	Overall weights
Service performance	0.5005	**(C1)**	**Number of passengers**	**0.5206**	**0.2605 (2)**
		(C2)	Amount of freight and mail	0.3296	0.1649 (3)
		(C3)	Aircraft movements	0.1498	0.0750 (4)
Financial performance	**0.4995**	**(D1)**	**Total revenue**	**0.4995**	**0.4995 (1)**

5.4.2 OVERALL WEIGHTS OF VS II

The overall weights of the VS II are shown in Table 5.12. Among these variables, in terms of the input perspective, the size of terminal area is the highest overall weighted variable, which indicates that it should be taken into consideration first in evaluation of the input aspect of airport performance. This is followed by the weighted variables, number of runways and number of employees.

In terms of the output perspective, number of passengers is the highest overall weighted variable, which indicates that it should first be taken into consideration in the evaluation of the output aspect of airport efficiency. This is followed by the overall weighted variables amount of freight and mail and aircraft movements.

Table 5.12: Weights of airport efficiency evaluation system (VS II)

Input			Output		
Criteria		Weights	Criteria		Weights
(A1)	Number of employees	0.1047 (3)	(B1)	**Number of passengers**	**0.5206 (1)**
(A2)	Number of runways	0.4362 (2)	(B2)	Amount of freight and mail	0.3296 (2)
(A3)	**Size of terminal Area**	**0.4590 (1)**	(B3)	Aircraft movements	0.1498 (3)

5.5 OVERALL WEIGHTS BASED ON AN ALTERNATIVE SCALE

In this section, five other alternative scales which can be used in the AHP method are compared with the Saaty 1-9 scale. Each of the pair-wise comparison matrices which were mentioned in previous sections need to be transformed into the alternative judgement scale values since these different scales are 9-unit and bounded scales and, therefore, it is easy to map pair-wise comparisons from exact positions on the 1-9 scale to any of these scales.

For example, referring to Table 4.7, in respect of the 1-9 scale, the verbal statement moderate importance, is associated with the scale values 3 (1-9), 2.7183 (e^{1-9}), 4(2^{1-9}), 1.2857 (9/9-9/1), 1.5000 (10/10-18/2), and 1.2536 (ø mapping) respectively. If the scale value is 5, then the position on the Saaty 1-9 scale is the 5th. The value on the 5th position of the alternative judgement scale value is 5 (1-9), 7.3891 (e^{1-9}), 16 (2^{1-9}), 1.8000 (9/9-9/1), 2.3333 (10/10-18/2), and 1.6125 (ø mapping). The preference evaluation procedure outlined in Section 4.4 can also be used in determining the alternative judgement scales. The weights can easily be calculated on the alternative judgement scale by transforming the importance from the questionnaire.

5.5.1 WEIGHTS OF THE VARIABLES IN VS I

5.5.1.1 INPUT PERSPECTIVE

The differences in the set of weights between the alternative scales and the comparisons in respect to the two aspects in the main criteria are provided in Table 5.13. The variety is identified clearly in Figure 5.3. In Table 5.13, the weight of the airport finances is the most important among these experts, but it also shows that there are differences in the weight which is calculated using alternative scales.

Airport capacity ranges from 0.4564 (which is calculated by scale 4) to 0.3059 (which is calculated by scale 3). The weight of financial variable ranges from 0.6941 (which is calculated by scale 3) to 0.5355 (which is calculated by scale 6). The weight of criteria for airport capacity and finances are computed by means of alternative judgement scales, and they are only slightly different. By conducting scale 2^{1-9}, the gap is the found to be the largest, and the gap in scale 6 is found to be the smallest.

Table 5.13: Weights of main-criteria variables in input perspective

	1	2	3	4	5	6
Main-Criteria	1-9	e^{1-9}	2^{1-9}	9/9-9/1	10/10-18/2	Ø mapping
(A) Airport capacity	0.3759	0.3564	0.3059	0.4564	0.4374	0.4645
(B) Airport finances	**0.6241**	**0.6436**	**0.6941**	**0.5436**	**0.5626**	**0.5355**

Figure 5.3: Weights of main-criteria

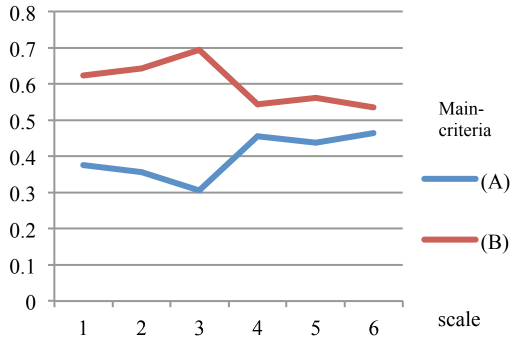
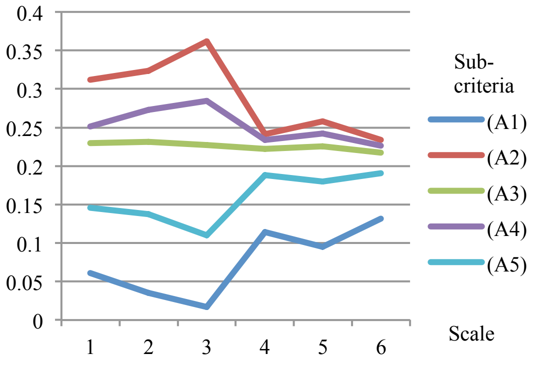


Figure 5.4: Weights of sub-criteria



In Table 5.13, if the 6 scales are separated into two groups (scale 1-3) and (scale 4-6), the results show identical ranking orders and similar sets of weights in these two groups. This is perhaps because of the verbal statement of importance. From Table 4.7, it can be seen that the values which represent importance among scale (1-9), (e^{1-9}), and (2^{1-9}), are similar and that the values among scale (9/9-9/1), (10/10-18/2), and (ø mapping) are similar, too. In this case, finances can be positioned at moderate importance as compared to airport capacity. From Table 4.7 the moderate importance is associated with the scale values 3(1-9), 2.7183 (e^{1-9}), 4(2^{1-9}), 1.2857(9/9-9/1), 1.5000(10/10-18/2), and 1.2536 (ø mapping) respectively. If using these value to do the calculation, the results will show the weights computed by scale (1-9), (e^{1-9}), and (2^{1-9}) will close, and the weights computed by scale (9/9-9/1), (10/10-18/2), and (ø mapping). This situation also occurs as shown in the following tables.

The weights of the sub-criteria from the input perspective are calculated and listed in Table 5.14. The variety can be identified clearly in Figure 5.4. In Table 5.14, the overall weights of each variable are represented in the value in brackets, and the number in each column means the rank of each sub-criterion. From Figure 5.4, by conducting scale 3, the difference is the largest and in scale 6 is the smallest. The weight of the number of gates is the most important variable, even when calculated by alternative scales as an airport capacity variable. On the other hand, the number of employees is the least important variable. The ranking of these five variables in different scales are all the same. Table 5.14 also shows that the weights that are computed by scales 1 to 3 are close and that the weights which are computed by scale 4 to 6 are also close.

Table: 5.14: Weights of sub-criteria variables in input perspective

	1	2	3	4	5	6
Sub-Criteria	1-9	e^{1-9}	2^{1-9}	9/9-9/1	10/10-18/2	∅ mapping
(A1) Number of employees	0.0607 (0.0228) 6	0.0349 (0.0124) 6	0.0166 (0.0051) 6	0.1143 (0.0522) 6	0.0953 (0.0417) 6	0.1320 (0.0613) 6
(A2) Number of gates	**0.3122** **(0.1173)** **2**	**0.3236** **(0.1153)** **2**	**0.3621** **(0.1108)** **2**	**0.2417** **(0.1205)** **2**	**0.2578** **(0.1128)** **2**	**0.2339** **(0.1087)** **2**
(A3) Number of runways	0.2299 (0.0864) 4	0.2316 (0.0825) 4	0.2273 (0.0695) 4	0.2220 (0.1053) 4	0.2254 (0.0986) 4	0.2173 (0.1009) 4
(A4) Size of terminal area	0.2516 (0.0946) 3	0.2725 (0.0971) 3	0.2842 (0.0869) 3	0.2336 (0.1106) 3	0.2419 (0.1058) 3	0.2260 (0.1050) 3
(A5) Length of runway	0.1457 (0.0547) 5	0.1374 (0.0490) 5	0.1099 (0.0336) 5	0.1885 (0.0825) 5	0.1796 (0.0786) 5	0.1908 (0.0886) 5
(B1) Operational expenditure	**0.6241** **1**	**0.6436** **1**	**0.6941** **1**	**0.5436** **1**	**0.5626** **1**	**0.5355** **1**

5.5.1.2 OUTPUT PERSPECTIVE

The weights of the main criteria for output are listed in Table 5.15, and the variations are further illustrated in Figure 5.5. The weights between criteria service performance and financial performance using scale 3 indicate that the variety is the largest and that in scale 1 it is the smallest. By means of scale 1, it can be seen that service performance of an airport is more important than financial performance. On the other hand, by adopting the rest of the five scales have reverse results.

Table 5.15: Weights of main-criteria variables in output perspective

	1	2	3	4	5	6
Main Criteria	1-9	e^{1-9}	2^{1-9}	9/9-9/1	10/10-18/2	∅ mapping
(C) Service performance	**0.5005** **1**	0.4943 2	0.4921 2	0.4976 2	0.4973 2	0.4984 2
(D) Financial performance	0.4995 2	**0.5057** **1**	**0.5079** **1**	**0.5024** **1**	**0.5027** **1**	**0.5016** **1**

Figure 5.5: Weights of main criteria

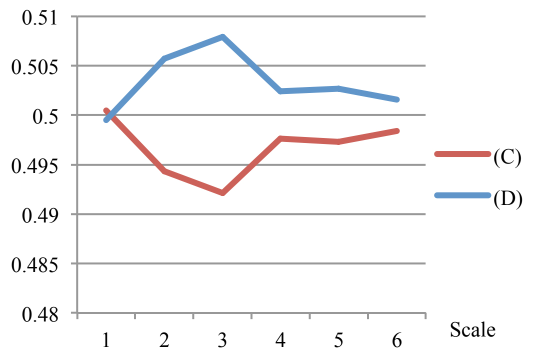
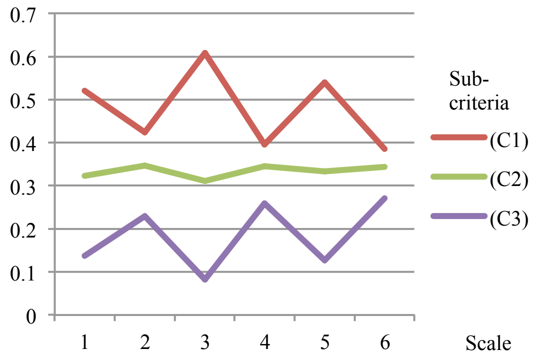


Figure 5.6: Weights of sub-criteria



Pöyhönen and Hämäläinen (2001) revealed that the rank of variables may remain the same even when there remains a difference in the criteria weights. However, from Figure 5.5, a very interesting point needs to be discussed. In the previous figures (Figure 5.3 and Figure 5.4), the rank of the variable is not changed when conducting alternative scales, but in Table 5.15 and Figure 5.5, the criteria for service performance and financial performance are in different order when using the 1-9 scale to calculate the weight. From this, although the rank changes, the evidence still shows that alternative scales can help provide different weights. In this case, the difference between service performance and financial performance by using not only scale 1-9 but also other scales is slight. In general, all experts felt these two variables both to be very important when evaluating airport efficiency.

The weights for the main criteria from the output perspective are listed in Table 5.16, and the differences are illustrated in Figure 5.6. The weights among these three variables on alternative judgement are only slightly different. By conducting scale 3, the difference is the largest, and scale 6 is the smallest. In addition, the ranking of these five variables in different scales are all the same, and among these output variables, total revenue is the most import variables when evaluation airport efficiency.

Table 5.16: Weight of sub-criteria variables in output perspective

	1	2	3	4	5	6
Sub-Criteria	1-9	e^{1-9}	2^{1-9}	9/9-9/1	10/10-18/2	Ø mapping
(C1) Number of passengers	**0.5206** **(0.2605)** **2**	**0.5402** **(0.2670)** **2**	**0.6078** **(0.2991)** **2**	**0.3962** **(0.2213)** **2**	**0.4245** **(0.2111)** **2**	**0.3850** **(0.1919)** **2**
(C2) Amount of freight and mail	0.3296 (0.1649) 3	0.3327 (0.1644) 3	0.3104 (0.1527) 3	0.3454 (0.1803) 3	0.3462 (0.1722) 3	0.3432 (0.1711) 3
(C3) Aircraft movements	0.1498 (0.075) 4	0.1271 (0.0628) 4	0.0818 (0.0402) 4	0.2584 (0.1171) 4	0.2292 (0.1140) 4	0.2717 (0.1354) 4
(D1) Total revenue	**0.4995** **1**	**0.5057** **1**	**0.5079** **1**	**0.5024** **1**	**0.5027** **1**	**0.5016** **1**

5.5.2 WEIGHTS OF THE VARIABLES IN VS II

5.5.2.1 INPUT PERSPECTIVE

The weights of variables from the input perspective are calculated using alternative scales and are listed in Table 5.17. The differences are identified clearly in Figure 6.7. The weights among these criteria (which are computed by means of alternative judgement scales) are distributed significantly. By conducting scale 3, the variety is the largest, and using scale 6, it is the smallest. Using alternative scales, the number of runways is the most important variable as compared to others.

5.5.2.2 OUTPUT PERSPECTIVE

Table 5.17 also displays the weight of variables in the output. The differences are identified clearly in Figure 5.7. The weight among these three variables is distributed smoothly, and the rankings for each variable are the same. From Figure 5.7 and Figure 5.8, it can also be seen that the weights computed by scales 1 to 3 are similar, and the weights computed by scales 4 to 6 are similar.

Table 5.17: Weights of the variables in VS II

	Input					
	1	2	3	4	5	6
Criteria	1-9	e^{1-9}	2^{1-9}	9/9-9/1	10/10-18/2	Ø mapping
(A) Number of employees	0.1077 3	0.0634 3	0.0303 3	0.1985 3	0.1678 3	0.2280 3
(B) Number of runways	**0.4590** **1**	**0.4825** **1**	**0.5052** **1**	**0.4067** **1**	**0.4226** **1**	**0.3899** **1**
(C) Size of terminal area	0.4334 2	0.4541 2	0.4645 2	0.3949 2	0.4095 2	0.3821 2
	Output					
	1	2	3	4	5	6
Criteria	1-9	e^{1-9}	2^{1-9}	9/9-9/1	10/10-18/2	Ø mapping
(D) Number of passengers	**0.5206** **2**	**0.5402** **2**	**0.6078** **2**	**0.3962** **2**	**0.4245** **2**	**0.3850** **2**
(E) Amount of freight and mail	0.3296 3	0.3327 3	0.3104 3	0.3454 3	0.3462 3	0.3432 3
(F) Aircraft movements	0.1498 4	0.1271 4	0.0818 4	0.2584 4	0.2292 4	0.2717 4

Figure 5.7: Weights of criteria in input aspect

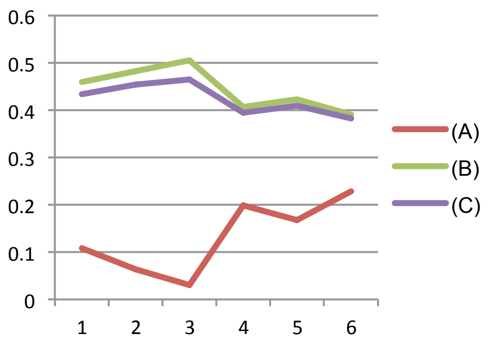
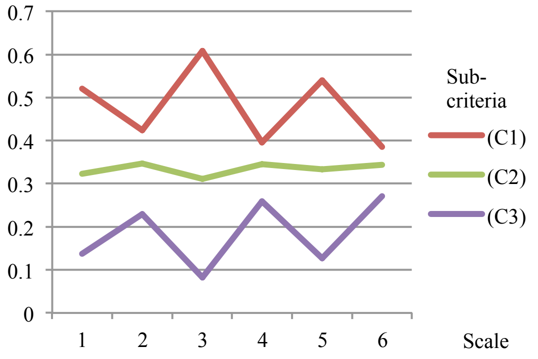


Figure 5.8: Weights of criteria in output aspect



5.5.3 ALTERNATIVE SCALES IN DIFFERENT GROUPS: VS I

This section discusses the results in three different groups: experts in academia, experts in a practical area, and overall experts.

5.5.3.1 MAIN-CRITERIA

In regard to the input perspective of VS I (see Table 5.18), when employing alternative scales, experts in practice felt the airport finances to be more important than airport capacity. This was the case with academia, too. These results are very similar to the overall results. The experts all believed that on the input side, finances in an airport operation should be given more consideration than airport capacity. Table 5.18 also shows that the weights which were computed using scales 1 to 3 are close and that the weights computed using scales 4 to 6 are also close.

Table 5.18: Weights of main-criteria in different scales by groups: input perspective

	1	2	3	4	5	6
Main-Criteria	1-9	e^{1-9}	2^{1-9}	9/9-9/1	10/10-18/2	$\emptyset$ mapping
Practice						
Airport capacity	0.3549 2	0.3245 2	0.2657 2	0.4445 2	0.4219 2	0.4555 2
Airport finances	**0.6450** **1**	**0.6756** **1**	**0.7343** **1**	**0.5555** **1**	**0.5781** **1**	**0.5445** **1**
Academia						
Airport capacity	0.4222 2	0.4290 2	0.4023 2	0.4821 2	0.4711 2	0.4838 2
Airport finances	**0.5778** **1**	**0.5710** **1**	**0.5977** **1**	**0.5179** **1**	**0.5289** **1**	**0.5161** **1**
Overall						
Airport capacity	0.3759 2	0.3564 2	0.3059 2	0.4564 2	0.4374 2	0.4645 2
Airport finances	**0.6241** **1**	**0.6436** **1**	**0.6941** **1**	**0.5436** **1**	**0.5626** **1**	**0.5355** **1**

From the output perspective (see Table 5.19), the experts from academia believed that service performance in an airport should be given more consideration than financial performance. Although this result is different from the experts in a practice, the gap is not very significant. The overall results are influenced by experts selected from practice rather than from academia. From Table 5.19, the weights in different groups can help to explain why the overall weight and rank which are calculated using scale 1 is different from those of other scales. Experts in academia felt service performance to be much more important than financial performance (i.e. 0.7439 and 0.2561), but experts in practice felt that financial performance is important than service performance (i.e. 0.5867 and 0.4133). After combining the weights in both groups, the results show that the importance of service performance is a little higher than that of financial performance. The situation is also occurred among the other scales.

Table 5.19: Weights of main-criteria in different scales by groups: output perspective

	1	2	3	4	5	6
Main-Criteria	1-9	e^{1-9}	2^{1-9}	9/9-9/1	10/10-18/2	$\emptyset$ mapping
Practice						
Service performance	0.4133 2	0.3933 2	0.3542 2	0.4830 2	0.4542 2	0.4741 2
Financial performance	**0.5867** **1**	**0.6067** **1**	**0.6458** **1**	**0.5170** **1**	**0.5458** **1**	**0.5259** **1**
Academia						
Service performance	**0.7439** **1**	**0.7625** **1**	**0.8344** **1**	**0.6193** **1**	**0.6193** **1**	**0.5679** **1**
Financial performance	0.2561 2	0.2375 2	0.1656 2	0.3807 2	0.3807 2	0.4321 2
Overall						
Service performance	**0.5005** **1**	0.4943 2	0.4921 2	0.4976 2	0.4973 2	0.4984 2
Financial performance	0.4995 2	**0.5057** **1**	**0.5079** **1**	**0.5024** **1**	**0.5027** **1**	**0.5016** **1**

5.5.3.2 SUB-CRITERIA

In the input perspective of VS I, there is a different opinion about the importance of the number of gates and the size of the terminal area among the experts from academia and practice. The ranking of other variables in different scales are all the same and are only different on weight values (further details are shown in Table 5.20).

In the output perspective of VS I, the ranking of other variables in different judgement scales are all the same and are only different in regard to weight values. (Details are shown in Table 5.21). Table 5.20 and Table 5.21 also show that the weights computed using scales 1 to 3 are similar and that the weights computed by scales 4 to 6 are close.

Table 5.20: Weights of sub-criteria of different scales by groups: input perspective

	1	2	3	4	5	6
Sub-Criteria	1-9	e^{1-9}	2^{1-9}	9/9-9/1	10/10-18/2	Ø mapping
Practice						
Number of employees	0.0576 (0.0205) 6	0.0311 (0.0101) 6	0.0140 (0.0037) 6	0.1089 (0.0484) 6	0.0904 (0.0381) 6	0.1279 (0.0582) 6
Number of gates	0.3336 (0.1184) 2	0.3506 (0.1138) 2	0.4015 (0.1067) 2	0.2498 (0.1111) 2	0.2688 (0.1134) 2	0.2401 (0.1093) 2
Number of runways	0.2239 (0.0795) 4	0.2289 (0.0742) 4	0.2226 (0.0591) 4	0.2235 (0.0994) 4	0.2257 (0.0952) 4	0.2180 (0.0993) 4
Size of terminal area	0.2354 (0.0836) 3	0.2486 (0.0807) 3	0.2489 (0.0661) 3	0.2276 (0.1012) 3	0.2332 (0.0984) 3	0.2217 (0.1010) 3
Length of runway	0.1495 (0.0531) 5	0.1407 (0.0457) 5	0.1129 (0.0300) 5	0.1902 (0.0845) 5	0.1820 (0.0768) 5	0.1924 (0.0876) 5
Operational expenditure	**0.6450** **1**	**0.6756** **1**	**0.7343** **1**	**0.5555** **1**	**0.5781** **1**	**0.5445** **1**
Academia						
Number of employees	0.0670 (0.0283) 6	0.0439 (0.0188) 6	0.0230 (0.0093) 6	0.1267 (0.0611) 6	0.1067 (0.0503) 6	0.1410 (0.0682) 6
Number of gates	0.2679 (0.1131) 3	0.2675 (0.1148) 3	0.2798 (0.1126) 3	0.2243 (0.1081) 3	0.2349 (0.1106) 3	0.2210 (0.1069) 3
Number of runways	0.2410 (0.1017) 4	0.2340 (0.1004) 4	0.2308 (0.0928) 4	0.2183 (0.1052) 4	0.2238 (0.1054) 4	0.2156 (0.1043) 4
Size of terminal area	0.2877 (0.1214) 2	0.3257 (0.1397) 2	0.3650 (0.1468) 2	0.2462 (0.1187) 2	0.2604 (0.1227) 2	0.2352 (0.1138) 2
Length of runway	0.1365 (0.0576) 5	0.1289 (0.0553) 5	0.1013 (0.0408) 5	0.1845 (0.0890) 5	0.1742 (0.0820) 5	0.1872 (0.0906) 5
Operational expenditure	**0.5778** **1**	**0.5710** **1**	**0.5977** **1**	**0.5179** **1**	**0.5289** **1**	**0.5161** **1**
Overall						
Number of employees	0.0607 (0.0228) 6	0.0349 (0.0124) 6	0.0166 (0.0051) 6	0.1143 (0.0522) 6	0.0953 (0.0417) 6	0.1320 (0.0613) 6
Number of gates	0.3122 (0.1173) 2	0.3236 (0.1153) 2	0.3621 (0.1108) 2	0.2417 (0.1205) 2	0.2578 (0.1128) 2	0.2339 (0.1087) 2
Number of runways	0.2299 (0.0864) 4	0.2316 (0.0825) 4	0.2273 (0.0695) 4	0.2220 (0.1053) 4	0.2254 (0.0986) 4	0.2173 (0.1009) 4
Size of terminal area	0.2516 (0.0946) 3	0.2725 (0.0971) 3	0.2842 (0.0869) 3	0.2336 (0.1106) 3	0.2419 (0.1058) 3	0.2260 (0.1050) 3
Length of runway	0.1457 (0.0547) 5	0.1374 (0.0490) 5	0.1099 (0.0336) 5	0.1885 (0.0825) 5	0.1796 (0.0786) 5	0.1908 (0.0886) 5
Operational expenditure	**0.6241** **1**	**0.6436** **1**	**0.6941** **1**	**0.5436** **1**	**0.5626** **1**	**0.5355** **1**

Table 5.21: Weights of sub-criteria of different scales by groups: output perspective

	1	2	3	4	5	6
Sub-Criteria	1-9	e^{1-9}	2^{1-9}	9/9-9/1	10/10-18/2	Ø mapping
Practice						
Number of passengers	0.5389 (0.2227) 2	0.5604 (0.2204) 2	0.6327 (0.2241) 2	0.4026 (0.1885) 2	0.4339 (0.1971) 2	0.3904 (0.1851) 2
Amount of freight and mail	0.3232 (0.1335) 3	0.3251 (0.1279) 3	0.2974 (0.1053) 3	0.3457 (0.1619) 3	0.3455 (0.1569) 3	0.3434 (0.1628) 3
Aircraft movements	0.1379 (0.0570) 4	0.1144 (0.0450) 4	0.0699 (0.0248) 4	0.2517 (0.1179) 4	0.2206 (0.1002) 4	0.2662 (0.1263) 4
Total revenues	**0.5867** **1**	**0.6067** **1**	**0.6458** **1**	**0.5318** **1**	**0.5458** **1**	**0.5259** **1**
Academia						
Number of passengers	0.4804 (0.3270) 2	0.4954 (0.3478) 2	0.5511 (0.4224) 2	0.3826 (0.2144) 2	0.4043 (0.2381) 2	0.3736 (0.2056) 2
Amount of freight and mail	0.3417 (0.2326) 3	0.3466 (0.2433) 3	0.3359 (0.2574) 3	0.3445 (0.1930) 3	0.3472 (0.2044) 3	0.3427 (0.1886) 3
Aircraft movements	0.1779 (0.1211) 4	0.1580 (0.1109) 4	0.1130 (0.0866) 4	0.2729 (0.1529) 4	0.2485 (0.1463) 4	0.2837 (0.1561) 4
Total revenue	**0.3193** **1**	**0.2979** **1**	**0.2336** **1**	**0.4396** **1**	**0.4112** **1**	**0.4497** **1**
Overall						
Number of passengers	0.5206 (0.2605) 2	0.5402 (0.2670) 2	0.6078 (0.2991) 2	0.3962 (0.2213) 2	0.4245 (0.2111) 2	0.3850 (0.1919) 2
Amount of freight and mail	0.3296 (0.1649) 3	0.3327 (0.1644) 3	0.3104 (0.1527) 3	0.3454 (0.1803) 3	0.3462 (0.1722) 3	0.3432 (0.1711) 3
Aircraft movements	0.1498 (0.075) 4	0.1271 (0.0628) 4	0.0818 (0.0402) 4	0.2584 (0.1171) 4	0.2292 (0.1140) 4	0.2717 (0.1354) 4
Total revenue	**0.4995** **1**	**0.5057** **1**	**0.5079** **1**	**0.5024** **1**	**0.5027** **1**	**0.5016** **1**

5.5.4 ALTERNATIVE SCALES IN DIFFERENT GROUPS: VS II

In the input perspective of VS II, there is a difference of opinion about the importance of the number of runways and the size of the terminal area among the experts from academia and practice. The ranking of other variables in different scales are all the same and are only different with regard to weight values (further details are shown in Table 5.22).

In the output perspective of VS II, the ranking of all variables in different scales are all the same and only differ in weight values (further details are shown in Table 5.23).

Table 5.22: Weights of different scales by groups: input perspective

	1	2	3	4	5	6
Sub-Criteria	1-9	e^{1-9}	2^{1-9}	9/9-9/1	10/10-18/2	Ø mapping
Practice						
Number of employees	0.1035 3	0.0550 3	0.0248 3	0.1891 3	0.1569 3	0.2194 3
Number of runways	**0.4505** **1**	**0.4751** **1**	**0.4914** **1**	**0.4167** **1**	**0.4238** **1**	**0.3921** **1**
Size of terminal area	0.4459 2	0.4699 2	0.4839 2	0.3942 2	0.4192 2	0.3885 2
Academia						
Number of employees	0.1071 3	0.0646 3	0.0309 3	0.2050 3	0.1717 3	0.2319 3
Number of runways	0.4059 2	0.3851 2	0.3670 2	0.3744 2	0.3793 2	0.3652 2
Size of terminal area	**0.4870** **1**	**0.5504** **1**	**0.6021** **1**	**0.4206** **1**	**0.4490** **1**	**0.4030** **1**
Overall						
Number of employees	0.1077 3	0.0634 3	0.0303 3	0.1985 3	0.1678 3	0.2280 3
Number of runways	**0.4590** **1**	**0.4825** **1**	**0.5052** **1**	**0.4067** **1**	**0.4226** **1**	**0.3899** **1**
Size of terminal area	0.4334 2	0.4541 2	0.4645 2	0.3949 2	0.4095 2	0.3821 2

Table 5.23: Weights of different scales by groups: output perspective

	1	2	3	4	5	6
Sub-Criteria	1-9	e^{1-9}	2^{1-9}	9/9-9/1	10/10-18/2	$\emptyset$ mapping
Practice						
Number of passengers	**0.5389** **1**	**0.5604** **1**	**0.6327** **1**	**0.4026** **1**	**0.4339** **1**	**0.3904** **1**
Amount of freight and mail	0.3232 2	0.3251 2	0.2974 2	0.3457 2	0.3455 2	0.3434 2
Aircraft movements	0.1379 3	0.1144 3	0.0699 3	0.2517 3	0.2206 3	0.2662 3
Academia						
Number of passengers	**0.4804** **1**	**0.4954** **1**	**0.5511** **1**	**0.4083** **1**	**0.4043** **1**	**0.3629** **1**
Amount of freight and mail	0.3417 2	0.3466 2	0.3359 2	0.3481 2	0.3472 2	0.3428 2
Aircraft movements	0.1779 3	0.1580 3	0.1130 3	0.2436 3	0.2484 3	0.2943 3
Overall						
Number of passengers	**0.5206** **2**	**0.5402** **2**	**0.6078** **2**	**0.3962** **2**	**0.4245** **2**	**0.3850** **2**
Amount of freight and mail	0.3296 3	0.3327 3	0.3104 3	0.3454 3	0.3462 3	0.3432 3
Aircraft movements	0.1498 4	0.1271 4	0.0818 4	0.2584 4	0.2292 4	0.2717 4

5.6 CROSS DISCUSSION AND ANALYSIS

Comparing the weight of each variable with those reported in the literature review in Chapter 2, there are some points that can be discussed.

Firstly, from the literature, the variable number of employees has been the most widely used parameter when evaluating airport efficiency (in total, 27 of 66 papers). However, in this research, experts from both academia and practice felt this variable to be the least important variable because the experts felt that the number of employees can be included in operational expenditure. Therefore, other variables (such as size of terminal area, number of runways, and operational expenditure) were all considered to be first priority.

Furthermore, Table 5.11 also shows that the experts who were interviewed in this research felt that more emphasis should be placed on the finances, but the literature review shows that only around 10 papers used financial variables. This might be a result of data accessibility or research limitations. It is widely believed that financial data is the most difficult data to acquire. Secondly, the weights of each variable show significant differences when using alternative scales to calculate variable weights. From the results, there is proof that when conducting alternative scales in AHP analysis, the weights of each variable will change. In addition, in order to determine the further influence of alternative scales on airport efficiency, it is necessary to combine the weights of each variable with the DEA model.

5.7 SUMMARY

This chapter demonstrated how the earlier concepts and analysis methods (see Chapter 2 and Chapter 4) were applied to acquire the weights of each variable. This chapter also provided a description of the interview and questionnaire techniques that were adopted in this study. The results of AHP analysis indicate that experts from the practical area placed more emphasis on the value of financial variables than the experts from academia. The use of alternative judgement scales in this research and their application were also described in this chapter. From this comparison of the results using a 1-9 scale, it appears that different scales can obtain different weights. Therefore, this provides strong evidence to support the view that no single benchmark for the choice of scales should be used in this research. In the next chapter, the weights that are calculated by alternative scales are combined with the DEA model to compute the relative efficiency of the 24 sample airports.

CHAPTER 6

AIRPORT EFFICIENCY ANALYSIS I:
BASIC DEA MODELS AND
INTEGRATED AHP/DEA MODEL

This chapter presents an analysis of the relative efficiency scores of the sample airports by means of variable weights. The first section describes the concepts and analysis process for the efficiency scores. The second and third sections present the efficiency scores as computed using basic DEA models. Section four calculates the efficiency scores by using an integrated AHP/DEA model. Finally, the empirical results cross discussion and conclusions are provided.

6.1 CONCEPTS OF AIRPORT EFFICIENCY ANALYSIS

A set of balanced panel data are required to evaluate the efficiency of the 24 sample airports examined in this research. The data set is acquired from two major sources, which include the 2010 ATRS airport benchmarking report and the annual reports published by the individual airports. In order to conduct sensitivity analysis, this research uses two variables sets (a ten variables set and a six variables set) to calculate airport efficiency.

6.1.1 THE DEA MODELS IN THIS RESEARCH

There are two basic models in the DEA method (the CCR and BCC). The choice of a DEA model depends on the assumptions regarding the variable sets to be employed and on the prior results about the industry to be studied. The variable sets have to describe the activities of the units in the best possible way. It is particularly important to have some idea about the hypothetical returns to scale that exist in the industry (Martin and Roman 2001). The literature review in Section 4.6 indicated that DEA can be carried out under the assumption of CRS for the inputs and outputs in the DEA-CCR model or by introducing a scale constraint into the model under conditions of VRS in a DEA-BCC model. The VRS scores calculate pure technical efficiency only. However, the CRS index is composed of a non-additive combination of pure technical and scale efficiencies (which is usually called technical efficiency) (Cooper et al. 2006; Barros and Dieke 2007).

6.1.2 THE ORIENTATION OF THE DEA MODEL

Once the selection of a DEA model has been made, an orientation of the model to determine the measurement of the efficiency is needed. There are two basic orientations, which include both input and output. An input orientation focuses on the proportional decrease of the input vector while the output orientation adjusts the proportional increase of the output (Martin and Roman 2001). The samples involved in this research determine the selection of the orientation. An output orientation is employed in this research because once an airport has invested in something such as the building of new runways or new terminals, it is difficult for airport authorities to disinvest to save costs by amending their input variables (i.e. runways, terminal buildings, or employees) to invalidate the input orientation (Gillen and Lall; 1997; Oum 2006).

6.1.3 THE DEA ANALYSIS PROCESS

The process for analysing the operating efficiency is divided into five parts:

(1) Validity test of the variables

Isotonicity is one of the tests that can be performed to check the validity of the inputs and outputs chosen. This concept means that the outputs should be significant and positively correlated with the inputs (Charnes et al. 1985). In this research, a correlation coefficients analysis is applied to determine the relations between the input and output variables.

(2) Analysis of operating efficiency

The five evaluation items include the categories of airport ownership and governance, the technical efficiency (i.e. CRS efficiency), the pure technical efficiency (i.e. VRS efficiency), the scale efficiency, and the returns to scale. The technical efficiency can be obtained from the CCR model while the BCC model can be used to obtain the pure technical efficiency. The technical efficiency is then divided by the pure technical efficiency in order to get the scale efficiency. The obtained efficiency values are used then to analyse the operating efficiency of each airport. In addition, Coelli et al. (2005) revealed the concept that the assumption in a DEA-CCR model is that all DMUs are operating at an optimal scale. However, imperfect competition, government regulations, and constraints on finance may all cause a firm to not operate at an optimal scale. When not all DMUs are operating at the optimal scale, the use of the DEA-BCC model specification is more suitable to assess airport efficiency. Therefore, in the following section, more emphasis is placed on the results from the DEA-BCC (i.e. output-oriented) model.

(3) Clustering analysis referral

The purpose of the clustering analysis referral is to view the relatively efficient airports, which are then used as the references and frequencies that improve the efficiencies of relatively inefficient enterprises (Zhu 2009). The more an airport is referred, the more efficient the airport is in the DMU group; therefore, improvements in the operating flow of an inefficient airport can be more reachable.

(4) Slack variable analysis

A slack variable analysis can provide guidance for the researcher or manager to find any improper resource allocation and utilisation in the DMU; hence, a relatively inefficient DMU can help determine how to adjust inputs in order to increase outputs. Analysis of the different variables is separated into the CCR model and the BCC model. The CCR model (i.e. the slack variable analysis of CRS efficiency) represents the long-term direction of the DMUs while the BCC model (the slack variable analysis of VRS efficiency) represents the short-term improvment direction of the DMUs (Cooper et al. 2006).

(5) Hypothesis testing

Having established the efficiency rankings of the sample airports, the hypotheses related to the rankings obtained need to be tested. The Mann–Whitney U-test, which tests for differences between the efficiency scores, is adopted in the current research. Golany and Roll (1989) recommended the use of the Mann–Whitney U-test for the non-parametric analysis of DEA results that is used in this study because the efficiency scores do not follow a standard normal distribution. In this research, this test can help us answer Research Question 2:

Would an airport privatisation policy (airport ownership) influence the performance of an airport's operation?

6.2 AIRPORT EFFICIENCY ANALYSIS: VS I

Two different variable sets are applied in the DEA analysis in this research (as described in Chapter 4). VS I (which includes ten variables) is conducted to evaluate airport efficiency, and the results are described in the subsections which follow.

6.2.1 RELATIONS BETWEEN VARIABLES

Before conducting efficiency analysis, a correlation coefficients analysis is applied to determine the relations between the input and output variables. Table 6.1 presents all of the relations between each input and output variable. The results show that all of the variables can satisfy the isotonicity test properly, which means that an output should not decrease with an increased input. All of the correlation coefficients are positive in

VS I. Therefore, all of the different resources and facilities are generally dimensioned jointly to avoid conflict.

Table 6.1: Correlation coefficients among input and output variables: VS I

	Input Variables					
Output Variables	Number of Employees	Number of Gates	Number of Runways	Size of Terminal Area	Length of Runway	Operational Expenditures
Number of passengers	0.340	0.632**	0.280	0.312	0.281	0.662**
Amount of freight and mail	0.230	0.190	0.070	0.532**	0.313	0.297
Aircraft movements	0.452*	0.584**	0.480*	0.135	0.187	0.640**
Total revenue	0.439*	0.725**	0.145	0.181	0.233	0.932**

**Correlation is significant at the 0.01 level (2-tailed)
* Correlation is significant at the 0.05 level (2-tailed)

6.2.2. RELATIVE EFFICIENCY ANALYSIS

The panel data for VS I are shown in Table 6.2, while the columns for variables in VS II are highlighted in shadow. Table 6.3 shows the five evaluation items that were used for airport efficiency and sample character. The first column shows the ownership category of each airport, the second column presents the CRS technical efficiency measure, the third and fourth columns are the VRS pure technical efficiency and the scale efficiency, respectively. The fifth column indicates whether the DMU is operating in an area of increasing or decreasing returns to scale. In addition, in order to discern the influence of airport ownership on airport efficiency, the separation of the sample airports into private operation and public operation is based on their property status.

In this research, 24 sample airports are classified into seven different categories, which are based on their airport ownership and governance. To compare the results easily, these sample airports are separated into two groups: publicly operated and privately operated. There are 15 airports that are run by the public sector (most of them are in the Asia-Pacific region), and nine airports are run by private companies (see Table 6.4).

Table 6.2: Panel data of sample airports

	Input Variables						**Output Variables**			
	Number of Employees	Number of Gates	Number of Runways	Size of Terminal Area (m^2)	Length of Runway (ft)	Operational Expenditure ($million)	Number of Passengers (000's)	Amount of Freight and Mails (tons)	Aircraft Movements (times)	Total Revenues ($million)
Amsterdam (AMS)	2579	94	6	591885	3244	985.64	47430	1567712	446693	1602.42
Barcelona (BCN)	569	101	3	155200	2850	290.36	30208	104239	321491	324.03
Frankfurt (FRA)	17996	174	3	800000	4000	1851.29	53467	2111116	485783	2104.52
Istanbul (IST)	1750	32	3	318500	2767	172.04	28533	766221	254531	283.98
London (LGW)	2186	107	1	202519	3316	584.43	34214	112366	263653	854.14
London (LHR)	5516	264	2	364800	3780	1820.23	67056	1486262	478693	2891.66
Madrid (MAD)	797	76	4	300000	3863	580.71	50846	328985	469740	647.92
Munich (MUC)	7400	200	2	458000	4000	1063.23	34552	274464	432296	1368.4
Paris (CDG)	3858	124	4	542595	3454	1084.6	60875	2040000	559812	1768.92
Paris (ORY)	3304	102	3	371500	3123	497.65	26210	140000	230167	732.32
Rome (FCO)	3278	86	4	285000	3677	477.66	35227	137424	346654	948.93
Zurich (ZRH)	1254	67	3	138614	3167	401.63	22099	387671	274991	789.76
Bangkok (BKK)	3245	120	2	563000	3850	432.04	46932	1291931	311435	733.69
Beijing (PEK)	1965	120	3	1382000	3600	517.26	55938	1367710	429646	561.6
Guangzhou (CAN)	3482	74	2	320000	3700	235.65	33435	685868	280392	378.69
Hong Kong (HKG)	1131	106	2	710000	3800	425.23	47700	3400000	296000	1120.93
Incheon (ICN)	933	90	3	600000	3833	396.64	29973	2423717	211102	973.92
Kuala Lumpur (KUL)	1578	106	2	479404	4090	256.8	27529	667495	209681	292.24
Osaka (KIX)	388	52	2	330000	3750	458.45	16014	846522	133502	959.15
Tokyo (HRT)	720	87	2	789700	3250	1109.51	32654	2100448	193321	1830.69
Shanghai (PVG)	6440	98	3	824000	3733	212.15	28236	2603027	265735	482.15
Singapore (SIN)	1396	102	3	1043020	3583	402.63	22877	415726	185304	921.99
Shenzhen (SZX)	3998	55	1	152000	3400	95.52	21401	598036	187942	217.22
Sydney (SYD)	306	65	3	387487	2978	136.47	32900	470000	298964	773.69

Source: ATRS (2010).

An examination of Table 6.3 reveals that 17 of 24 airports are operated relatively efficiently when using the CCR model to calculate airport efficiency, and 19 of 24 airports are relatively efficient when employing the BCC model to calculate airport efficiency. A number of points emerge by means of the basic DEA models:

(1) Too many airports are on the efficient frontier; hence it is difficult to help airport authorities to improve their operations (i.e. obtaining scores on the CCR and BCC of unity).

(2) Best practice calculations indicate that almost all European airports are operated at a high level of relative efficiency, with the exception of Paris (ORY).

(3) All efficient airports determined by the CCR model are also efficient in the BCC model, signifying that the dominant source of efficiency is scale; that is: $S\ efficiency\ (Technical\ efficiency{:}\,TE) =$ $VRS\ efficiency\ (Pure\ technical\ efficnency{:}\,PTE) \times Scale\ efficiency\ (SE)$.

(4) The rationale for interpreting the BCC model as management skills is based on the contrast between the CCR and BCC models. The CCR model identifies the overall inefficiency while the BCC differentiates between technical efficiency and scale efficiency (Golany and Roll, 1989). Based on this differentiation, the ratio between the CCR and BCC models enables the estimation of scale efficiency, and, assuming that efficiency is due to managerial skills and scale effects, the BCC scores are interpreted as managerial skills. Therefore, according to the BCC scores, five airports are found to be inefficient.

(5) According to the scale efficiency, there are only seven airports that are operated relatively inefficiently.

(6) Three situations are listed in the last column. If output increases by the same proportional change, then there are CRS, by less than the proportional change, then there are DRS, and by more than that proportional change, then there are IRS (Coelli et. al. 2005). Consequently, the returns to scale faced by an airport are purely technologically imposed and are not influenced by economic decisions or by market conditions. Therefore, from Table 6.3, four of the airports are found to need to decrease their scale, and three of the airports are found to need to increase their scale.

Table 6.3: Efficiency scores obtained by basic DEA model: VS I

No.	**DMU**	**Ownership category**	**CCR model (CRS)**	**BCC model (VRS)**	**Scale* efficiency**	**RTS**
	European					
1	Amsterdam (AMS)	B	1	1	1	-
2	Barcelona (BCN)	F	1	1	1	-
3	Frankfurt (FRA)	C E	0.9899	1	0.9899	DRS
4	Istanbul (IST)	D	1	1	1	-
5	London (LGW)	G	1	1	1	-
6	London (LHR)	G	1	1	1	-
7	Madrid (MAD)	F	1	1	1	-
8	Munich (MUC)	E	1	1	1	-
9	Paris (CDG)	B	1	1	1	-
10	**Paris (ORY)**	**B**	**0.6500**	**0.6551**	**0.9924**	**IRS**
11	Rome (FCO)	B	0.9711	0.9948	0.9728	DRS
12	Zurich (ZRH)	B	1	1	1	-
	Mean		0.9676	0.9708	0.9963	
	Asia-Pacific					
13	Bangkok (BKK)	C	1	1	1	-
14	Beijing (PEK)	C	1	1	1	-
15	Guangzhou (CAN)	C	0.9983	1	0.9983	DRS
16	Hong Kong (HKG)	F	1	1	1	-
17	Incheon (ICN)	F	0.9391	0.9418	0.9971	IRS
18	Kuala Lumpur (KUL)	F	0.7890	0.8844	0.8791	IRS
19	Osaka (KIX)	C E	1	1	1	-
20	Tokyo (HRT)	F	1	1	1	-
21	Shanghai (PVG)	F	1	1	1	-
22	Singapore (SIN)	**A**	0.7878	0.8318	0.9471	DRS
23	Shenzhen (SZX)	C	1	1	1	-
24	Sydney (SYD)	B	1	1	1	-
	Mean		0.9595	0.9715	0.9851	
Mean of all samples			0.9635	0.9712	0.9907	
	S.D		0.0896	0.0786	0.0266	

(7) Among these inefficient airports in CCR and BCC model, only Paris (ORY) is relatively smaller than other airports and it is far away from the other results (0.6500 in CRS efficiency and 0.6551 in VRS efficiency).

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* The scale efficiency is the quotient obtained by the division of the technical efficiency with constant returns to scale and variable returns to scale (Cooper et al 2006). If this scale efficiency is near one, it expresses that the airport is near to the optimal scale of operations. The area of operation has been obtained by running a DEA problem with non-increasing returns to scale.

(8) From Table 6.4, the BCC model identifies five airports as being inefficient. According to ownership category, two of them are privately operated (i.e. Paris: ORY and Rome: FCO), and three of them are publicly operated (i.e. Singapore: SIN, Incheon: ICN, and Kuala Lumpur: KUL).

(9) Table 6.4 also reveals that the efficiency of publicly operated airports is better than that of those that are privately operated. However, in general, only ORY has a relatively lower efficiency score and the efficiency scores for other private airports were all higher.

Table 6.4: Airport efficiency with different ownership: VS I

DMU	Ownership category*	CCR model (CRS)	BCC model (VRS)	Scale efficiency
Amsterdam (AMS)	(A)	1	1	1
Istanbul (IST)	(A)	1	1	1
London (LGW)	(A)	1	1	1
London (LHR)	(A)	1	1	1
Paris (CDG)	(A)	1	1	1
Paris (ORY)	(A)	**0.6500**	**0.6551**	**0.9924**
Rome (FCO)	(A)	0.9711	0.9983	0.9728
Zurich (ZRH)	(A)	1	1	1
Sydney (SYD)	(A)	1	1	1
Mean		0.9579	0.9615	0.9961
S.D		0.1159	0.1149	0.0091
Barcelona (BCN)	(B)	1	1	1
Frankfurt (FRA)	(B)	0.9899	1	0.9899
Madrid (MAD)	(B)	1	1	1
Munich (MUC)	(B)	1	1	1
Bangkok (BKK)	(B)	1	1	1
Beijing (PEK)	(B)	1	1	1
Guangzhou (CAN)	(B)	0.9983	1	0.9983
Hong Kong (HKG)	(B)	1	1	1
Incheon (ICN)	(B)	0.9391	0.9418	0.9971
Kuala Lumpur (KUL)	(B)	0.7890	0.8975	0.8791
Osaka (KIX)	(B)	1	1	1
Tokyo (HRT)	(B)	1	1	1
Shanghai (PVG)	(B)	1	1	1
Singapore (SIN)	(B)	0.7878	0.8318	0.9471
Shenzhen (SZX)	(B)	1	1	1
Mean		0.9669	0.9780	0.9874
S.D.		0.0741	0.05	0.0329

*(A) represents privately operated airports; (B) represents publicly operated airports.

6.2.3 THE CLUSTERING ANALYSIS REFERRAL

Table 6.5 shows the referral frequency for every airport in the BCC model. The results of the analysis show that Sydney airport has the highest referral frequency (i.e. 5). The airports that referred to Sydney are Paris (ORY), Rome, Incheon, Kuala Lumpur, and Singapore. London (LHR) has the second highest referral frequency (i.e. 3). The airports that referred to LHR are Paris (ORY), Rome, and Singapore. A further nine relatively efficient airports were also referred. The result of this analysis indicates that, among these 17 efficient airports, Sydney and London (Heathrow) are the most relatively efficient.

Table 6.5: The referral of clustering analysis: VS I

No.	DMU	Referral Clustering	Referral Frequency	No.	DMU	Referral Clustering	Referral Frequency
1	Amsterdam (AMS)	1	1	13	Bangkok (BKK)	13	0
2	Barcelona (BCN)	2	1	14	Beijing (PEK)	14	0
3	Frankfurt (FRA)	3	0	15	Guangzhou (CAN)	15	0
4	Istanbul (IST)	4	2	16	Hong Kong (HKG)	16	2
5	London (LGW)	5	0	17	Incheon (ICN)	4, 16, 19, 24	0
6	**London (LHR)**	**6**	**3**	18	Kuala Lumpur (KUL)	16, 19, 23, 24	0
7	Madrid (MAD)	7	1	19	Osaka (KIX)	19	2
8	Munich (MUC)	8	0	20	Tokyo (HRT)	20	0
9	Paris (CDG)	9	2	21	Shanghai (PVG)	21	0
10	Paris (ORY)	1, 2, 4, 6, 9, 12, 24	0	22	Singapore (SIN)	6, 24	0
11	Rome (FCO)	6, 7, 9, 12, 24	0	23	Shenzhen (SZX)	23	1
12	Zurich (ZRH)	12	2	**24**	**Sydney (SYD)**	**24**	**5**

6.2.4 THE SLACK VARIABLE ANALYSIS

As mentioned in Section 6.1.2, the results of the slack analysis can only provide guidance by which inefficient airports can improve their efficiency. Sometime this guidance is difficult to achieve. The results of slack analysis by individual airport are listed from Table 6.6 to Table 6.9. In the analysis of difference variables of CRS efficiency (from Table 6.6 and 6.7), 7 of the 24 airports are shown to be inefficient. Therefore, from the input variables, it is recommended that these seven airports over the long-term should reach an efficient output by reducing (on average) the number of employees by 2673.58, the number of gates by 4.02, the number of runways by 0.2, the size of terminal area by 115,397 m^2, the length of runways by 188.73 m, and their operational expenditures by \$82.07 million. Among the output variables, they are recommended (on average) to raise the number of passengers by 8694.04, the amount of freight and mail by 422680.6 tonnes, the aircraft movements by 60053.39, and total revenue by \$182.02 million. Among the output variables (on average), they are recommended to raise the number of passengers by 8694.051, the amount of freight and mail by 422680.6 tonnes, the aircraft movements 60053.38, and the total revenue by \$182.018 million to become efficient.

In the analysis of different variables of VRS efficiency (as shown in Tables 6.8 and 6.9), five of the twenty-four airports are shown to be inefficient. Therefore, from the input variables, in the short-term, these five airports are recommended (on average) to reduce their employees by 801.22, the number of gates by 8.95, the number of runways by 0.37, the size of terminal area by 148,810 m^2, and their length of runways by 335.70m to become efficient. Among the output variables (on average), they are recommended to raise the number of passengers by 8466.59, the amount of freight and mail by 424317.2 tonnes, the aircraft movements 69303.78, and the total revenue by \$216.48 million to become efficient.

Table 6.6: Long-term projection of individual airports (1): VS I

	Number of employees	Number of gates	Number of runways	Size of terminal area (m2)	Length of runway	Operational expenditure (million $)
Frankfurt (FRA) 0.9899						
Actual data	17996	174	3	800000	4000	1851.29
Projection	4006.68	174	3	533283.74	3731.47	1276.81
Difference	-13989.32	0	0	-266716.26	-268.53	-574.48
%	-77.74%	0	0	-33.34%	-6.71%	-31.03%
Paris (ORY) 0.6500						
Actual data	3304	102	3.00	371500	3123	497.65
Projection	1454.88	102	2.96	371500	3123	497.65
Difference	-1849.12	0	-0.04	0	0	0
%	-55.97%	0	-1.39%	0	0	0
Rome (FCO) 0.9711						
Actual data	3278	86	4	285000	3677	477.66
Projection	1293.38	86	3.56	285000	3677	477.66
Difference	-1984.62	0	-0.44	0	0	0
%	-60.54%	0	-10.89%	0	0	0
Guangzhou (CAN) 0.9983						
Actual data	3482	74	2	320000	3700	235.65
Projection	2967.31	74	2	320000	3700	235.65
Difference	-514.69	0	0	0	0	0
%	-14.78%	0	0	0	0	0
Incheon (ICN) 0.9391						
Actual data	933	90	3	600000	3833	396.64
Projection	892.61	90	2.06	594904.02	3643.09	396.64
Difference	-40.39	0	-0.94	-5095.98	-189.91	0
%	-4.33%	0	-31.46%	-0.85%	-4.95%	0
Kuala Lumpur (KUL) 0.7890						
Actual data	1578	106	2	479404	4090	256.80
Projection	1578	77.84	2	479404	3227.34	256.80
Difference	0	-28.16	0	0	-862.66	0
%	0	-26.57%	0	0	-21.09%	0
Singapore (SIN) 0.7878						
Actual data	1396	102	3	1043020	3583	402.63
Projection	1059.07	102	3	507056.42	3583	402.63
Difference	-336.93	0	0	-535963.58	0	0
%	-24.14%	0	0	-51.39%	0	0
Average	**-2673.58**	**-4.02286**	**-0.20286**	**-115397**	**-188.729**	**-82.0686**
	-33.93%	**-3.80%**	**-6.25%**	**-12.23%**	**-4.68%**	**-4.43%**

Table 6.7: Long-term projection of individual airports (2): VSI

	Number of passengers (000's)	Amount of freight and mails (tonnes)	Aircraft movements	Total revenue (million $)
Frankfurt (FRA) 0.9899				
Actual data	53467	2111116	485783	2104.52
Projection	61778.97	2132565.9	490718.78	2125.90
Difference	8311.97	21449.90	4935.78	21.38
%	15.55%	1.02%	1.02%	1.02%
Paris (ORY) 0.6500				
Actual data	26210	140000	230167	732.32
Projection	40325.93	737637.08	354128.09	1126.73
Difference	14115.93	597637.08	123961.09	394.41
%	53.86%	426.88%	53.86%	53.86%
Rome (FCO) 0.9711				
Actual data	35227	137424	346654	948.93
Projection	36277.09	553791.61	369256.44	977.22
Difference	1050.09	416367.61	22602.44	28.29
%	2.98%	302.98%	6.52%	2.98%
Guangzhou (CAN) 0.9983				
Actual data	33435	685868	280392	378.69
Projection	33493.58	817069.73	280883.25	488.33
Difference	58.58	131201.73	491.25	109.64
%	0.18%	19.13%	0.18%	28.95%
Incheon (ICN) 0.9391				
Actual data	29973	2423717	211102	973.92
Projection	39445.47	2580934.56	260070.49	1037.095
Difference	9472.47	157217.56	48968.49	63.18
%	31.60%	6.49%	23.20%	6.49%
Kuala Lumpur (KUL) 0.7890				
Actual data	27529	667495	209681	292.24
Projection	34888.84	1415738.2	265738.87	701.11
Difference	7359.84	748243.2	56057.87	408.87
%	26.73%	112.10%	26.73%	139.91%
Singapore (SIN) 0.7878				
Actual data	22877	415726	185304	921.99
Projection	43366.48	1302373.14	348660.75	1170.35
Difference	20489.48	886647.14	163356.75	248.356
%	89.56%	213.28%	88.16%	26.94%
Average	**8694.051**	**422680.6**	**60053.38**	**182.018**
	31.49%	**154.55%**	**28.52%**	**37.16%**

Table 6.8: Short-term projection of individual airports (1): VSI

	Number of employees	Number of gates	Number of runways	Size of terminal area (m2)	Length of runway	Operational expenditure (million $)
Paris (ORY) 0.6551						
Actual data	3304	102	3.00	371500	3123	497.65
Projection	1502.33	102	2.99	371500	3123	497.65
Difference	-1801.66	0	-0.01	0	0	0
%	-54.53%	0	-0.44%	0	0	0
Rome (FCO) 0.9983						
Actual data	3278	86	4	285000	3677	477.66
Projection	1340.50	81.98	3.20	285000	3269.50	477.66
Difference	-1937.5	-4.02	-0.80	0	-407.51	0
%	-59.11%	-4.67%	-20.03%	0	-11.08%	0
Incheon (ICN) 0.9418						
Actual data	933	90	3	600000	3833	396.64
Projection	932.50	90	2.12	597838.4	3682.98	396.64
Difference	-0.50	0	-0.88	-2161.56	-150.02	0
%	-0.05%	0	-29.21%	-0.36%	-3.91%	0
Kuala Lumpur (KUL) 0.8975						
Actual data	1578	106	2	479404	4090	256.80
Projection	1578	70.80	2	396636.6	3447.26	256.80
Difference	0	-35.20	0	-82767.4	-642.74	0
%	0	-33.21%	0	-17.26%	-15.71%	0
Singapore (SIN) 0.8318						
Actual data	1396	102	3	1043020	3583	402.63
Projection	1129.57	96.46	2.84	383900.8	3104.78	402.63
Difference	-266.43	-5.54	-0.16	-659119	-478.22	0
%	-19.09%	-5.43%	-5.27%	-63.19%	-13.35%	0
Average	**-801.218**	**-8.952**	**-0.37**	**-148810**	**-335.698**	**0**
	-26.56%	**-8.66%**	**-10.99%**	**-16.16%**	**-8.81%**	**0.00%**

Table 6.9: Short-term projection of individual airports (2): VSI

	Number of passengers (000's)	Amount of freight and mails (tonnes)	Aircraft movements	Total revenue (million $)
Paris (ORY) 0.6551				
Actual data	26210	140000	230167	732.32
Projection	40008.76	747131	351342.8	1117.86
Difference	13798.76	607131	121175.8	385.54
%	52.65%	433.66%	52.65%	52.65%
Rome (FCO) 0.9983				
Actual data	35227	137424	346654	948.93
Projection	35285.8	608342.9	347232.7	950.51
Difference	58.80	470918.9	578.66	1.58
%	0.17%	342.68%	0.17%	0.17%
Incheon (ICN) 0.9418				
Actual data	29973	2423717	211102	973.92
Projection	39883.68	2573498	265049.3	1034.11
Difference	9910.68	14978.5	53947.28	60.19
%	33.07%	6.18%	25.56%	6.18%
Kuala Lumpur (KUL) 0.8975				
Actual data	27529	667495	209681	292.24
Projection	30671.52	1346330	238427.6	740.83
Difference	3142.52	678835.4	28746.58	448.59
%	11.42%	101.70%	13.71%	153.50%
Singapore (SIN) 0.8318				
Actual data	22877	415726	185304	921.99
Projection	38299.2	630645.4	327374.6	1108.49
Difference	15422.2	214919.4	142070.6	186.50
%	67.41%	51.70%	76.67%	20.23%
Average	**8466.592**	**397356.6**	**69303.78**	**216.48**
	32.94%	**187.18%**	**33.75%**	**46.55%**

6.2.5 HYPOTHESIS TESTING

The separation of sample airports into private operation and public operation is based on their property status. In this research, 24 sample airports are classified into seven different categories that are based on airport ownership and governance. In order to answer research questions, these airports are separated into two groups: public sector operation and private company operation. There are 15 airports under the public sector (most of them are in Asia-Pacific) and nine airports under private companies. This section puts forward the hypothesis to be tested as follows:

Hypothesis: Airports under private management are more efficient than those under public management.

Table 6.10 presents the Mann–Whitney test results. The minus sign of the Z-score indicates that privately managed airports are found to have higher efficiency scores than publicly managed facilities, thus validating the hypothesis that private airports are more efficient than their public counterparts (Parker 1999). It also shows that the z-value is −0.126, with a significance level (p) of p = 0.900. The probability value (p) is not less than or equal to 0.05, so the result is not significant. Therefore, there is no statistically significant difference in airport efficiency between privately operated and publicly operated airports. However, this result is quite different from the common opinion that private companies can be operated more efficiently than those in the public sector. Therefore, sensitivity analysis is conducted in the following section in order to determine if this result is reliable.

Table 6.10: Mann-Whitney test of differences in efficiency: VS I

Reference	Mann-Whitney *U*-test	Mann-Whitney *Z*-test	Asymptotic Significance (two-tailed)
Privately managed airports vs. publicly managed airports	66.00	−0.126	0.900

6.3 AIRPORT EFFICIENCY ANALYSIS: VS II

In this section, VS II (which includes six variables) is used to conduct one kind of sensitivity analysis (i.e. another one using another analysis tool is undertaken in the next section). The five steps that are used to analyse airport efficiency are described in the subsections which follow.

6.3.1 RELATIONS BETWEEN VARIABLES

Before conducting efficiency analysis it is also necessary to apply a correlation coefficients analysis to understand the relations between the input and output variables in this variable set. Table 6.11 shows all of the correlation coefficients of all variables in VS II to be positive. Therefore, all of the different resources and facilities are dimensioned jointly to avoid conflict.

Table 6.11: Correlation coefficients among inputs and outputs variables: VS II

	Input Variables		
Output Variables	Number of Employees	Number of Runways	Size of Terminal Area
Number of passengers	0.340	0.280	0.312
Amount of freight and mail	0.230	0.070	0.532**
Aircraft movements	0.452*	0.480*	0.135

**Correlation is significant at the 0.01 level (2-tailed)
*Correlation is significant at the 0.05 level (2-tailed)

6.3.2 RELATIVE EFFICIENCY ANALYSIS

The panel data for VS II are shown in Table 6.2. It indicates that 6 of the 24 airports are found to be operated relatively efficiently when analysed using a CCR model to calculate airport efficiency while 12 of the 24 airports are found to be operated relatively efficiently when a BCC model is used to calculate airport efficiency. A number of points emerge from Table 6.12 and Table 6.13 including:

(1) There are relatively fewer efficient airports as compared to inefficient airports when comparison is conducted using Table 6.3.

(2) Best practice calculations indicate that European airports are operated relatively more efficiently than Asian airports. This is shown from the efficiency average.

(3) All of the efficient CRS airports are also efficient in the VRS model, signifying that the dominant source of efficiency is scale.

(4) According to the scale efficiency, there are seven airports that are operated relatively efficiently.

(5) Twelve of the inefficient airports need to decrease their scale, and four of them need to increase their scale.

(6) Among the inefficient airports, Paris (ORY) (0.4305 in the CRS model; 0.4810 in the BCC model) and Singapore (0.4423 in the CRS model; 0.4579 in the BCC model) are relatively smaller than other airports.

(7) The results shown in Table 6.13 reveal that when using the CCR model, the efficiency of privately operated airports is better than that of those that are publicly operated. However, when using BCC model, public airports are shown to achieve better efficiency, as mentioned in the previous section. The results from the BCC model are closer to the real world than those of the CCR model. Therefore, by means of VS II, publicly operated airports can get higher efficiency as compared to those that are operated privately. However, in general, only ORY had a relatively lower efficiency score, and the efficiency of other private airports all was higher.

Table 6.12: Efficiency scores obtained using basic DEA model: VS II

No.	DMU	Ownership Category	CCR Model (CRS)	BCC Model (VRS)	Scale Efficiency	RTS
	European					
1	Amsterdam (AMS)	B	0.7120	0.9010	0.7902	DRS
2	Barcelona (BCN)	F	1	1	1	-
3	Frankfurt (FRA)	C E	0.7384	0.9996	0.7387	DRS
4	Istanbul (IST)	D	0.6930	0.7046	0.9835	DRS
5	London (LGW)	G	1	1	1	-
6	London (LHR)	G	1	1	1	-
7	Madrid (MAD)	F	1	1	1	-
8	Munich (MUC)	E	0.8263	0.9030	0.9151	DRS
9	Paris (CDG)	B	0.9725	1	0.9725	DRS
10	**Paris (ORY)**	**B**	**0.4305**	**0.4810**	**0.8950**	**DRS**
11	Rome (FCO)	B	0.6803	0.7629	0.8917	DRS
12	Zurich (ZRH)	B	1	1	1	-
	Mean		0.8378	0.8960	0.9322	
	Asia-Pacific					
13	Bangkok (BKK)	C	0.7817	0.8229	0.9499	DRS
14	Beijing (PEK)	C	0.9276	1	0.9276	DRS
15	Guangzhou (CAN)	C	0.7036	0.7039	0.9996	-
16	Hong Kong (HKG)	F	1	1	1	-
17	Incheon (ICN)	F	0.8642	0.9061	0.9538	IRS
18	Kuala Lumpur (KUL)	F	0.6447	0.6493	0.9929	DRS
19	Osaka (KIX)	C E	0.8151	1	0.8151	IRS
20	Tokyo (HRT)	F	0.9956	1	0.9956	IRS
21	Shanghai (PVG)	F	0.6671	0.8065	0.8272	DRS
22	**Singapore (SIN)**	**A**	**0.4423**	**0.4579**	**0.9659**	**DRS**
23	Shenzhen (SZX)	C	0.9609	1	0.9609	IRS
24	Sydney (SYD)	B	1	1	1	-
	Mean		0.8169	0.8622	0.9490	
	Mean of all samples		0.8273	0.8791	0.9406	

Table 6.13: Airport efficiency in different ownership: VS II

DMU	Ownership category	CCR model (CRS)	BCC model (VRS)	Scale efficiency
Amsterdam (AMS)	(A)	0.7120	0.9010	0.7902
Istanbul (IST)	(A)	0.6930	0.7046	0.9835
London (LGW)	(A)	1	1	1
London (LHR)	(A)	1	1	1
Paris (CDG)	(A)	0.9725	1	0.9725
Paris (ORY)	(A)	**0.4305**	**0.4810**	0.8950
Rome (FCO)	(A)	0.6803	0.7629	0.8917
Zurich (ZRH)	(A)	1	1	1
Sydney (SYD)	(A)	1	1	1
Mean		0.8320	0.8722	0.9481
S.D		0.2093	0.1856	0.0738
Barcelona (BCN)	(B)	1	1	1
Frankfurt (FRA)	(B)	0.7384	0.9996	0.7387
Madrid (MAD)	(B)	1	1	1
Munich (MUC)	(B)	0.8263	0.9030	0.9151
Bangkok (BKK)	(B)	0.7817	0.8229	0.9499
Beijing (PEK)	(B)	0.9276	1	0.9276
Guangzhou (CAN)	(B)	0.7036	0.7039	0.9996
Hong Kong (HKG)	(B)	1	1	1
Incheon (ICN)	(B)	0.8642	0.9061	0.9538
Kuala Lumpur (KUL)	(B)	0.6447	0.6493	0.9929
Osaka (KIX)	(B)	0.8151	1	0.8151
Tokyo (HRT)	(B)	0.9956	1	0.9956
Shanghai (PVG)	(B)	0.6671	0.8065	0.8272
Singapore (SIN)	(B)	**0.4423**	**0.4579**	**0.9659**
Shenzhen (SZX)	(B)	0.9609	1	0.9609
Mean		0.8245	0.8833	0.9362
S.D.		0.1647	0.1663	0.0806

(A) represents privately operated airports; (B) represents publicly operated airports.

6.3.3 THE REFERRAL OF CLUSTERING ANALYSIS

Table 6.14 shows the referral frequency for the airports in the BCC model. The results show that Hong Kong Airport has the highest referral frequency (i.e. 9); it can be seen that the airports that referred to Hong Kong are Amsterdam, Frankfurt, Istanbul, Bangkok, Guangzhou, Incheon, Kuala Lumpur, Shanghai, and Singapore. Madrid has the second highest referral frequency (i.e. 7). This result indicates that Hong Kong and Madrid are relatively efficient among these airports that have an efficiency score of 1.

Table 6.14: The referrals in clustering analysis: VS II

No.	DMU	Referral Clustering	Referral Frequency	No.	DMU	Referral Clustering	Referral Frequency
1	Amsterdam (AMS)	16, 7, 9	0	13	Bangkok (BKK)	16, 6	0
2	Barcelona (BCN)	2	3	14	Beijing (PEK)	14	2
3	Frankfurt (FRA)	16, 9, 6	0	15	Guangzhou (CAN)	6, 16, 5, 7, 2	0
4	Istanbul (IST)	6, 16, 12, 9, 7	0	**16**	**Hong Kong (HKG)**	**16**	**9**
5	London (LGW)	5	3	17	Incheon (ICN)	16, 2 19	0
6	London (LHR)	6	6	18	Kuala Lumpur (KUL)	16, 7, 14, 5	0
7	**Madrid (MAD)**	**7**	**7**	19	Osaka (KIX)	19	1
8	Munich (MUC)	6	0	20	Tokyo (HRT)	20	0
9	Paris (CDG)	9	5	21	Shanghai (PVG)	16, 9	0
10	Paris (ORY)	6, 7, 9	0	22	Singapore (SIN)	14, 16, 7, 5	0
11	Rome (FCO)	7, 2	0	23	Shenzhen (SZX)	23	0
12	Zurich (ZRH)	12	1	24	Sydney (SYD)	24	0

6.3.4 THE SLACK VARIABLE ANALYSIS

As mentioned in Section 6.1.2, the results from slack analysis can only provide guidance by which inefficient airports can improve their efficiency. However, some of these suggestions are quite difficult to achieve in the case of airports. The results of slack analysis by individual airports are listed in Tables 6.15 to 6.18. In the analysis of difference variables of CRS efficiency (as shown in Table 6.15 and Table 6.16) 17 of the 24 airports were found to be inefficient. Therefore, for these 17 airports to reach an efficient output in the long-term, on average, they have to reduce their employees by 1271.09, the number of runways by 0.2, and the size of their terminal areas by 67,493.5m^2 (from the output variables). Among the output variables, on average, these airports are recommended to raise the number of passengers by 19,717.59, the amount of freight and mail by 739,865.2 tonnes, and aircraft movements by 110,799.8. The analysis of the different variables of VRS efficiency (as shown in Table 6.12) shows 12 of 24 airports to be inefficient. Therefore, in the short-term, these airports are recommended, on average, to reduce their employees by 1039.06, the number of runways by 0.20, and the size of their terminal areas by 76442.4 m^2 in order to reach an efficient output. Among the output variables, on average, they are recommended to raise their number of passengers by 20,145.81, their amount of freight and mail by 638,989.5 tonnes and their aircraft movements by 115,100.9 in order to obtain efficiency.

Table 6.15: Long-term projections for individual airports (1): VS II

	Input			Output		
	Number of Employees	Number of Runways	Size of Terminal Area (m^2)	Number of Passengers (000's)	Amount of Freight and Mails (tonnes)	Aircraft Movements
Amsterdam (AMS) 0.7120						
Actual data	2579	6	591885	47430	1567712	446693
Projection	2579	5.71	591885	66610.85	2201700	627337.1
Difference	0	-0.29	0	19180.85	633988	180644.1
%	0.00%	-4.79%	0.00%	40.44%	40.44%	40.44%
Frankfurt (FRA) 0.7384						
Actual data	17996	3	800000	53467	2111116	485783
Projection	6830.96	3	660800.8	94214.2	2859179	657917.7
Difference	-11165	0	-139199	40747.2	748062.9	172134.7
%	-62.04%	0.00%	-17.40%	76.21%	35.43%	35.43%
Istanbul (IST) 0.6930						
Actual data	1750	3	318500	28533	766221	254531
Projection	1750	2.99	318500	41174.36	1105690	367299.3
Difference	0	0.01	0	12641.36	339469.3	112768.3
%	0.00%	-0.30%	0.00%	44.30%	44.30%	44.30%
Munich (MUC) 0.8263						
Actual data	7400	2	458000	34552	274464	432296
Projection	4469.42	2	401611.5	68311.17	332157.4	523166.4
Difference	-2930.58	0	-56388.5	33759.17	57693.44	90870.37
%	-39.60%	0.00%	-12.31%	97.71%	21.02%	21.02%
Paris (CDG) 0.9725						
Actual data	3858	4	542595	60875	2040000	559812
Projection	3858	4	542595	70901.24	2097753	575660.5
Difference	0	0	0	10026.24	57753.37	15848.54
%	0.00%	0.00%	0.00%	16.47%	2.83%	2.83%
Paris (ORY) 0.4305						
Actual data	3304	3	371500	26210	140000	230167
Projection	3304	3	371500	64311.35	325168.9	534594
Difference	0	0	0	38101.35	185168.9	304427
%	0.00%	0.00%	0.00%	145.37%	132.26%	132.26%
Rome (FCO) 0.6803						
Actual data	3278	4	285000	35227	137424	346654
Projection	1822.09	4	285000	52868.11	202001.7	509552.3
Difference	-1455.91	0	0	17641.11	64577.75	162898.3
%	-44.41%	0.00%	0.00%	50.08%	46.99%	46.99%
Bangkok (BKK) 0.7817						
Actual data	3245	2	563000	46932	1291931	311435
Projection	3245	2	520246.6	60039.05	1652738	429165.5
Difference	0	0	-42753.4	13107.05	360807.3	117730.5
%	0.00%	0.00%	-7.59%	27.93%	27.93%	37.80%

Table 6.16: Long-term projections for individual airports (2): VS II

	Input			Output		
	Number of Employees	Number of Runways	Size of Terminal Area (m2)	Number of Passengers (000's)	Amount of Freight and Mails (tonnes)	Aircraft Movements
Beijing (PEK) 0.9276						
Actual data	1965	3	1382000	55938	1367710	429646
Projection	1965	3	1039735	73267.21	4836946	463162.5
Difference	0	0	-342265	17329.21	3469236	33516.5
%	0.00%	0.00%	-24.77%	30.98%	253.65%	7.80%
Guangzhou (CAN) 0.7036						
Actual data	3482	2	320000	33435	685868	280392
Projection	3482	2	320000	52945.4	974794	398508.8
Difference	0	0	0	19510.4	288926	118116.8
%	0.00%	0.00%	0.00%	58.35%	42.13%	42.13%
Incheon (ICN) 0.8642						
Actual data	933	3	600000	29973	2423717	211102
Projection	933	1.650926	585787.1	39357.95	2804581	244274.6
Difference	0	-1.35	-14212.9	9384.95	380863.8	33172.64
%	0.00%	-44.97%	-2.37%	31.31%	15.71%	15.71%
Kuala Lumpur (KUL) 0.6447						
Actual data	1578	2	479404	27529	667495	209681
Projection	1578	2	479404	45285.11	1777012	325248.1
Difference	0	0	0	17756.11	1109517	115567.1
%	0.00%	0.00%	0.00%	64.50%	166.22%	55.12%
Osaka (KIX) 0.8151						
Actual data	388	2	330000	16014	846522	133502
Projection	388	1.38522	299125.1	22048.67	1038489	163776.5
Difference	0	-0.61	-30874.9	6034.67	191967.2	30274.47
%	0.00%	-30.74%	-9.36%	37.68%	22.68%	22.68%
Tokyo (HRT) 0.9956						
Actual data	720	2	789700	32654	2100448	193321
Projection	720	1.57	475757.9	32798.28	2109729	215060.7
Difference	0	-0.43	-313942	144.28	9280.68	21739.67
%	0.00%	-21.38%	-39.75%	0.44%	0.44%	11.25%
Shanghai (PVG) 0.6671						
Actual data	6440	3	824000	28236	2603027	265735
Projection	2141.09	2.48	824000	62501.93	3902154	398358.8
Difference	-4298.92	-0.56	0	34265.93	1299127	132623.8
%	-66.75%	-17.19%	0.00%	121.36%	49.91%	49.91%
Singapore (SIN) 0.4423						
Actual data	1396	3	1043020	22877	415726	185304
Projection	1396	3	835266.2	62411.11	3772669	418922.1
Difference	0	0	-207754	39534.11	3356943	233618.1
%	0.00%	0.00%	-19.92%	172.81%	807.49%	126.07%
Shenzhen (SZX) 0.9609						
Actual data	3998	1	152000	21401	598036	187942
Projection	2239.89	0.82	152000	27436.08	622363.1	195587.2
Difference	-1758.11	-0.18	0	6035.08	24327.11	7645.17
%	-43.97%	-17.82%	0.00%	28.20%	4.07%	4.07%
Average	**-1271.09** **-15.10%**	**-0.20059** **-8.07%**	**-67493.5** **-7.85%**	**+19717.59** **+61.42%**	**+739865.2** **+100.79%**	**+110799.8** **+40.93%**

Table 6.17: Short-term projection of individual airports (1): VS II

	Input			Output		
	Number of Employees	Number of Runways	Size of Terminal Area (m2)	Number of Passengers (000's)	Amount of Freight and Mails (tonnes)	Aircraft Movements
Amsterdam (AMS) 0.9010						
Actual data	2579	6	591885	47430	1567712	446693
Projection	2579	3.712317	496397.2	56074.58	1739959	495771.8
Difference	0	-2.28768	-95487.8	8644.58	172246.9	49078.83
%	0.00%	-38.13%	-16.13%	18.23%	10.99%	10.99%
Frankfurt (FRA) 0.9996						
Actual data	17996	3	800000	53467	2111116	485783
Projection	3887.90	3	516605.2	60438.15	2111882	485959.3
Difference	-14108.1	0	-283395	6971.15	766.27	176.32
%	-78.40%	0.00%	-35.42%	13.04%	0.04%	0.04%
Istanbul (IST) 0.7046						
Actual data	1750	3	318500	28533	766221	254531
Projection	1750	2.98	318500	40494.95	1087445	361238.6
Difference	0	-0.02	0	11961.95	321224.5	106707.6
%	0.00%	-0.79%	0.00%	41.92%	41.92%	41.92%
Munich (MUC) 0.9030						
Actual data	7400	2	458000	34552	274464	432296
Projection	5516	2	364800	67056	1486262	478693
Difference	-1884	0	-93200	32504	1211798	46397
%	-25.46%	0.00%	-20.35%	94.07%	441.51%	10.73%
Paris (ORY) 0.4810						
Actual data	3304	3	371500	26210	140000	230167
Projection	3304	3	344089.9	59434.27	990072	478556.8
Difference	0	0	-27410.1	33224.27	850072	248389.8
%	0.00%	0.00%	-7.38%	126.76%	607.19%	107.92%
Rome (FCO) 0.7629						
Actual data	3278	4	285000	35227	137424	346654
Projection	773.38	3.90	285000	48708.09	305703.3	454382.7
Difference	-2504.62	-0.10	0	13481.09	168279.3	107728.7
%	-76.41%	-2.59%	0.00%	38.27%	122.45%	31.08%
Bangkok (BKK) 0.8229						
Actual data	3245	2	563000	46932	1291931	311435
Projection	3245	2	543579.7	57031.49	2477391	384075.9
Difference	0	0	-19420.3	10099.49	1185460	72640.94
%	0.00%	0.00%	-3.45%	21.52%	91.76%	23.32%
Guangzhou (CAN) 0.7039						
Actual data	3482	2	320000	33435	685868	280392
Projection	3482	2	320000	52857.72	974403.3	398349.1
Difference	0	0	0	19422.72	288535.3	117957.1
%	0.00%	0.00%	0.00%	58.09%	42.07%	42.07%
Incheon (ICN) 0.9061						
Actual data	933	3	600000	29973	2423717	211102
Projection	933	2.03	600000	39467.6	2674970	257543.4
Difference	0	-0.97	0	9494.60	251253.5	46441.4
%	0.00%	-32.25%	0.00%	31.68%	10.37%	22.00%

Table 6.18: Short-term projection of individual airports (2): VS II

	Input			Output		
	Number of Employees	Number of Runways	Size of Terminal Area (m2)	Number of Passengers (000's)	Amount of Freight and Mails (tonnes)	Aircraft Movements
Kuala Lumpur (KUL) 0.6493						
Actual data	1578	2	479404	27529	667495	209681
Projection	1578	2	409481.2	42398.45	1143050	322937.6
Difference	0	0	-69922.8	14869.45	475555.2	113256.6
%	0.00%	0.00%	-14.59%	54.01%	71.24%	54.01%
Shanghai (PVG) 0.8065						
Actual data	6440	3	824000	28236	2603027	265735
Projection	1477.05	2.25	688756.6	49371.88	3227419	329477.2
Difference	-4962.95	-0.75	-135243	21135.88	624391.7	63742.22
%	-77.06%	-24.87%	-16.41%	74.85%	23.99%	23.99%
Singapore (SIN) 0.4579						
Actual data	1396	3	1043020	22877	415726	185304
Projection	1396	3	700234.7	49957.79	1111286	404658.7
Difference	0	0	-342785	27080.79	695560.3	219354.7
%	0.00%	0.00%	-32.86%	118.38%	167.31%	118.38%
Average	**-1039.06**	**-0.20**	**-76442.4**	**20145.81**	**638989.5**	**115100.9**
	-19.88%	**-6.63%**	**-10.56%**	**68.63%**	**175.32%**	**48.17%**

6.3.5 Hypothesis testing

Having established the efficiency rankings of the sample airports, there is the need to test again the following hypothesis:

Hypothesis: Airports under private management are more efficient than those under public management.

To compare these results easily, the 24 sample airports are classified into two groups: those operated by the public sector and those operated by private companies. There are 15 airports in this study which were run by the public sector at the time of the study (most of them in the Asia-Pacific region) and nine airports that were run by private companies. From Table 6.19 it can be seen that the z-value is −0.127, with a significance level (p) of p = 0.899. The probability value (p) is not less than or equal to 0.05, so the result is not significant. Therefore, there is no statistically significant difference found in airport efficiency between privately operated and publicly operated airports.

Table 6.19: Mann-Whitney test of differences in efficiency: VS II

Reference	Mann-Whitney *U*-test	Mann-Whitney *Z*-test	Asymptotic Significance (two-tailed)
Privately managed airports vs. publicly managed airports	65.5	−0.127	0.899

6.4 AIRPORT EFFICIENCY ANALYSIS: INTEGRATED AHP/DEA MODEL

Another sensitivity analysis (applying a different analysis model), is conducted in this section. This section also aims to answer Research Question 1 and to provide further information about Research Question 3, which are:

Research Question 1: Does the result of airport efficiency vary by conducting different evaluation methods?

Research Question 3: Does the influence of alternative scales on the results of the AHP analysis cause a different weight for each variable?

An integrated AHP/DEA model (and alternative scales used when calculating weight of each variable) is used to assess airport efficiency as sensitivity analysis. Several AHP/DEA models have been used to assess efficiency in several different fields (see Section 4.6). In this research, the method that was proposed by Jyoti et al. (2008) was used in which they used an AHP survey to acquire the weight of each output variable by evaluating the judgements of 20 senior scientists and research and development managers. After calculations, the data were transformed into dimensionless values by computing the respective relative scores of each output variable. The relative weighted scores were computed by multiplying the relative measure. This research follows this process to assess airport efficiency by means of an integrated AHP/DEA model. In addition, it expands the integrated AHP/DEA model to include input variables, which is described in the following section.

6.4.1 THE PROCESS DESCRIPTION OF AIRPORT EFFICIENCY EVALUATION

To demonstrate the developed model, an illustration is taken to evaluate the efficiency of the 24 sample airports. The weights of each variable (which were determined as described in Chapter 5) are listed in Table 6.20 while the panel data for the sample airports is shown in Table 6.2. The panel data in Table 6.2 are transformed into dimensionless values by computing the respective relative scores of each variable for all airports, as shown in Table 6.21 (standardisation of the panel data). In Tables 6.22 the relative weighted scores are computed by multiplying the relative scores with the respective weight of the respective variables by 1-9 scale. Take Amsterdam airport as an example. The number of employees in this column is 0.3267, which is calculated as (14.33 × 0.0228). (Other results which are calculated with alternative scale are attached in Appendix III).

In addition, Coelli et al. (2005) revealed the concept that an assumption in a DEA-CCR model is that all DMUs are operating at an optimal scale. However, imperfect competition, government regulations, and constraints on finance may all cause a DMU to not operate at an optimal scale. When not all DMUs are operating at the optimal scale, the use of the DEA-BCC model specification is more suitable to assess airport efficiency. Therefore, in the following section, a DEA-BCC (i.e. output-oriented) model is adopted to compute relative efficiency scores. The results from the AHP/DEA model are shown in the following sections.

Table 6.20: Weights of variables in alternative scales

Input Variables								
	(1)	(2)	(3)	(4)	(5)	(6)		
Sub-Criteria	1-9	e^{1-9}	2^{1-9}	9/9-9/1	10/10-18/2	Ø mapping	Mean	S.D.
(A1) Number of employees	0.0228	0.0124	0.0051	0.0522	0.0417	0.0613	0.0326	0.0226
(A2) Number of gates	0.1173	0.1153	0.1108	0.1103	0.1128	0.1087	0.1125	0.0033
(A3) Number of runways	0.0864	0.0825	0.0695	0.1013	0.0986	0.1009	0.0899	0.0127
(A4) Size of terminal area	0.0946	0.0971	0.0869	0.1066	0.1058	0.1050	0.0993	0.0079
(A5) Length of runway	0.0547	0.0490	0.0336	0.0860	0.0786	0.0886	0.0651	0.0225
(B1) Operational cost	0.6241	0.6436	0.6941	0.5436	0.5626	0.5355	0.6006	0.0634

Output Variables								
Sub-Criteria	(1) 1-9	(2) e^{1-9}	(3) 2^{1-9}	(4) 9/9-9/1	(5) 10/10-18/2	(6) Ø mapping	Mean	S.D.
(C1) Number of passengers	0.2605	0.2670	0.2991	0.2213	0.2111	0.1919	0.2418	0.0403
(C2) Amount of freight and mail	0.1649	0.1644	0.1527	0.1803	0.1722	0.1711	0.1676	0.0093
(C3) Aircraft movement	0.0750	0.0628	0.0402	0.1171	0.1140	0.1354	0.0908	0.0369
(D1) Total revenue	0.4995	0.5057	0.5079	0.5024	0.5027	0.5016	0.5033	0.0030

Table 6.21: Relative input and output scores

	Relative Input Score of DMUs						Relative Output Score of DMUs			
	Number of Employees	Number of Gates	Number of Runways	Size of Terminal Area	Length of Runway	Operational Expenditure	Number of Passengers	Amount of Freight and Mails	Aircraft Movements	Total Revenues
Amsterdam (AMS)	14.33	35.61	100	42.83	79.32	53.24	70.73	46.11	79.79	55.42
Barcelona (BCN)	3.16	38.26	50	11.23	69.68	15.68	45.05	3.07	57.43	11.21
Frankfurt (FRA)	100	65.91	50	57.89	97.80	100	79.73	62.09	86.78	72.78
Istanbul (IST)	9.72	12.12	50	23.05	67.65	09.29	42.55	22.54	45.47	9.82
London (LGW)	12.15	40.53	16.67	14.65	81.08	31.57	51.02	3.30	47.10	29.54
London (LHR)	30.65	100	33.33	26.40	92.42	98.32	100	43.71	85.51	100
Madrid (MAD)	4.43	28.79	66.67	21.71	94.45	31.37	75.83	9.68	83.91	22.41
Munich (MUC)	41.12	75.76	33.33	33.14	97.80	57.43	51.53	8.07	77.22	47.32
Paris (CDG)	21.44	46.97	66.67	39.26	84.45	58.59	90.78	60.00	100	61.17
Paris (ORY)	18.36	38.64	50	26.88	76.36	26.88	39.09	4.12	41.12	25.33
Rome (FCO)	18.22	32.58	66.67	20.62	89.90	25.80	52.53	4.04	61.92	32.82
Zurich (ZRH)	6.97	25.38	50	10.03	77.43	21.69	41.01	11.40	49.12	27.31
Bangkok (BKK)	18.03	45.46	33.33	40.74	94.13	23.34	69.99	38.00	55.63	25.37
Beijing (PEK)	10.92	45.46	33.33	100	88.02	27.94	83.42	40.23	76.75	19.42
Guangzhou (CAN)	19.35	28.03	33.33	23.15	90.46	12.73	49.86	28.30	37.71	13.10
Hong Kong (HKG)	6.28	40.15	33.33	51.37	92.91	22.97	71.13	100	52.87	38.76
Incheon (ICN)	5.18	34.09	50	43.42	93.72	21.43	44.70	71.29	37.71	33.68
Kuala Lumpur (KUL)	8.77	40.15	33.33	34.69	100	13.87	41.05	19.63	37.46	10.11
Osaka (KIX)	2.16	19.70	33.33	23.88	91.69	24.76	23.88	24.90	23.85	33.17
Tokyo (HRT)	4	32.96	33.33	57.14	79.46	59.93	48.70	61.78	34.53	63.31
Shanghai (PVG)	35.79	37.12	50	59.62	91.27	11.46	42.11	76.56	47.47	16.67
Singapore (SIN)	7.76	38.64	50	75.47	87.60	21.75	34.12	12.23	33.10	31.88
Shenzhen (SZX)	22.22	20.83	16.67	11	83.13	5.16	31.92	17.59	33.57	07.51
Sydney (SYD)	1.70	24.62	50	28.04	72.81	73.7	49.06	13.82	53.40	26.76

Table 6.22: Relative weighted input and output scores (scale 1-9)

	Relative Weighted Input Score Obtained by the DMUs						**Relative Weighted Output Score Obtained by the DMUs**			
1-9 weights	0.0228	0.1173	0.0864	0.0946	0.0547	0.6241	0.2227	0.1335	0.0570	0.5867
	Number of Employees	Number of Gates	Number of Runways	Size of Terminal Area	Length of Runway	Operational Expenditure	Number of Passengers	Amount of Freight and Mails	Aircraft Movements	Total Revenues
Amsterdam (AMS)	0.3267	4.1766	8.64	4.0515	4.3385	33.2275	15.7516	6.1557	4.5480	32.5149
Barcelona (BCN)	0.0721	4.4877	4.32	1.0624	3.8116	9.7885	10.0326	0.4098	3.2735	6.5769
Frankfurt (FRA)	2.2800	7.7311	4.32	5.4761	5.3497	62.4100	17.7559	8.2890	4.9465	42.7000
Istanbul (IST)	0.2217	1.4218	4.32	2.1802	3.7006	5.7997	9.4759	3.0091	2.5918	5.7614
London (LGW)	0.2770	4.7542	1.44	1.3863	4.4349	19.7021	11.3622	0.4406	2.6847	17.3311
London (LHR)	0.6988	11.7300	2.88	2.4971	5.0554	61.3629	22.2700	5.8353	4.8741	58.6700
Madrid (MAD)	0.1010	3.3768	5.76	2.0535	5.1664	19.5767	16.8873	1.2923	4.7829	13.1479
Munich (MUC)	0.9375	8.8864	2.88	3.1351	5.3497	35.8432	11.4757	1.0773	4.4015	27.7626
Paris (CDG)	0.4888	5.5096	5.76	3.7141	4.6194	36.5636	20.2167	8.0100	5.7000	35.8884
Paris (ORY)	0.4186	4.5320	4.32	2.5430	4.1767	16.7766	8.7053	0.5500	2.3438	14.8611
Rome (FCO)	0.4153	3.8212	5.76	1.9509	4.9176	16.1027	11.6984	0.5393	3.5294	19.2555
Zurich (ZRH)	0.1589	2.9770	4.32	0.9488	4.2356	13.5396	9.1329	1.5219	2.7998	16.0228
Bangkok (BKK)	0.4111	5.3319	2.88	3.8538	5.1490	14.5648	15.5868	5.0730	3.1709	14.8846
Beijing (PEK)	0.2490	5.3319	2.88	9.4600	4.8147	17.4377	18.5776	5.3707	4.3748	11.3937
Guangzhou (CAN)	0.4412	3.2880	2.88	2.1904	4.9484	7.9441	11.1038	3.7781	2.1495	7.6858
Hong Kong (HKG)	0.1433	4.7098	2.88	4.8601	5.0822	14.3352	15.8407	13.3500	3.0136	22.7405
Incheon (ICN)	0.1182	3.9989	4.32	4.1071	5.1263	13.3714	9.9547	9.5172	2.1495	19.7601
Kuala Lumpur (KUL)	0.1999	4.7098	2.88	3.2816	5.4700	8.6571	9.1418	2.6206	2.1352	5.9315
Osaka (KIX)	0.0492	2.3105	2.88	2.2589	5.0153	15.4551	5.3181	3.3242	1.3595	19.4608
Tokyo (HRT)	0.0912	3.8656	2.88	5.4056	4.3466	37.4034	10.8455	8.2476	1.9682	37.1440
Shanghai (PVG)	0.8159	4.3543	4.32	5.6404	4.9925	7.1519	9.3779	10.2208	2.7058	9.7803
Singapore (SIN)	0.1769	4.5320	4.32	7.1396	4.7919	13.5733	7.5985	1.6327	1.8867	18.7040
Shenzhen (SZX)	0.5065	2.4437	1.44	1.0405	4.5472	3.2201	7.1086	2.3483	1.9135	4.4061
Sydney (SYD)	0.0388	2.8880	4.32	2.6524	3.9828	4.6006	10.9257	1.8450	3.0438	15.7001

6.4.2 RELATIVE EFFICIENCY ANALYSIS: VS I

Table 6.23 shows that six evaluation items used to determine airport efficiency. The first column shows relative efficiency scores that are calculated using the original DEA-BCC model; the second shows the relative efficiency scores that are calculated using the integrated AHP/DEA model (the weights of each variable are considered using a 1-9 scale). Columns third to seven reveal the relative efficiency scores that are computed using the integrated AHP/DEA model (the weights of each variable are considered in alternative scales).

An examination of VS I reveals that 5 of the 24 airports are operated relatively inefficiently when using the BCC model and AHP/DEA model to calculate airport efficiency. A number of points emerge from Table 6.23 and Table 6.24, including:

(1) The number of relatively efficient airports is greater than the number of inefficient airports (by means of different scale). This is similar to the results which were calculated using the basic DEA model.

(2) Best practice calculations indicate that European airports are operated relatively more efficiently than Asian airports, which happens in all scales.

(3) The situation occurring in the AHP analysis (Chapter 6) is not discovered in Table 6.23, which is that when conducting alternative scales, the weights in scales 1 to 3 are close, and the weights in scales 4-6 are also close.

(4) Among these inefficient airports, Paris (ORY) has the lowest relative efficiency (0.6551) in the BCC model, but Singapore has the lowest relative efficiency (0.6672) in all AHP/DEA models, and both of them are far away from the others under consideration in this study.

(5) The discriminatory power of the results does not improve significantly when compared with the relative efficient scores between the BCC model and the AHP/DEA model (1-9 scale). In addition, the scores that are calculated by alternative scales do not noticeably improve either.

(6) Among the efficiency scores, the integrated AHP/DEA model provides most of the airports relative efficiency scores, with the exception of five airports (i.e. FRA, ORY, ICN, KUL, and SIN). Meanwhile, in the BCC model, FRA is found to operate efficiently, but FCO is not. However, the efficiency score reveals that there are only slight differences when conducting alternative judgement scales in the AHP/DEA model.

(7) The results shown in Table 6.24 indicate that when using the BCC model, public airports can achieve better efficiency. However, when conducting the integrated AHP/DEA model the results show that private operated airports can get higher efficiency than public ones by conducting six different scales. However, in general, only Singapore gets relative lower efficiency scores, and the efficiency of other private airports is all higher.

Table: 6.23: Efficiency scores obtained by AHP/DEA model: VS I

DMU	BCC	1-9	e^{1-9}	2^{1-9}	9/9-9/1	10/10-18/2	$\emptyset$ mapping
Europe							
Amsterdam (AMS)	1	1	1	1	1	1	1
Barcelona (BCN)	1	1	1	1	1	1	1
Frankfurt (FRA)	1	0.9996	0.9996	0.9996	0.9996	0.9996	0.9996
Istanbul (IST)	1	1	1	1	1	1	1
London (LGW)	1	1	1	1	1	1	1
London (LHR)	1	1	1	1	1	1	1
Madrid (MAD)	1	1	1	1	1	1	1
Munich (MUC)	1	1	1	1	1	1	1
Paris (CDG)	1	1	1	1	1	1	1
Paris (ORY)	0.6551	0.8205	0.8205	0.8205	0.8205	0.8205	0.8205
Rome (FCO)	0.9948	1	1	1	1	1	1
Zurich (ZRH)	1	1	1	1	1	1	1
Mean	0.9708	0.9850	0.9850	0.9850	0.9850	0.9850	0.9850
Asia-Pacific							
Bangkok (BKK)	1	1	1	1	1	1	1
Beijing (PEK)	1	1	1	1	1	1	1
Guangzhou (CAN)	1	1	1	1	1	1	1
Hong Kong (HKG)	1	1	1	1	1	1	1
Incheon (ICN)	0.9418	0.9944	0.9944	0.9944	0.9944	0.9944	0.9944
Kuala Lumpur (KUL)	0.8845	0.8975	0.8975	0.8975	0.8975	0.8975	0.8975
Osaka (KIX)	1	1	1	1	1	1	1
Tokyo (HRT)	1	1	1	1	1	1	1
Shanghai (PVG)	1	1	1	1	1	1	1
Singapore (SIN)	**0.8318**	**0.6672**	**0.6672**	**0.6672**	**0.6672**	**0.6672**	**0.6672**
Shenzhen (SZX)	1	1	1	1	1	1	1
Sydney (SYD)	1	1	1	1	1	1	1
Mean	0.9715	0.9633	0.9633	0.9633	0.9633	0.9633	0.9633
Mean of all samples	0.9712	0.9737	0.9737	0.9737	0.9737	0.9737	0.9737

(8) The results for referral frequency for the airports in the AHP/DEA model shows Hong Kong and Sydney to have the highest referral frequency (i.e. 4). The results indicate that Hong Kong and Sydney are relatively efficient among these airports that have an efficiency score of 1.

Table 6.24: Airport efficiency under different ownership: VS I

DMU	Ownership category*	BCC	1-9	e^{1-9}	2^{1-9}	9/9-9/1	10/10-18/2	Ø mapping
Amsterdam (AMS)	(A)	1	1	1	1	1	1	1
Istanbul (IST)	(A)	1	1	1	1	1	1	1
London (LGW)	(A)	1	1	1	1	1	1	1
London (LHR)	(A)	1	1	1	1	1	1	1
Paris (CDG)	(A)	1	1	1	1	1	1	1
Paris (ORY)	(A)	0.6551	0.8205	0.8205	0.8205	0.8205	0.8205	0.8205
Rome (FCO)	(A)	0.9983	1	1	1	1	1	1
Zurich (ZRH)	(A)	1	1	1	1	1	1	1
Sydney (SYD)	(A)	1	1	1	1	1	1	1
Mean		0.9615	0.9801	0.9801	0.9801	0.9801	0.9801	0.9801
S.D		0.1149	0.0598	0.0598	0.0598	0.0598	0.0598	0.0598
Barcelona (BCN)	(B)	1	1	1	1	1	1	1
Frankfurt (FRA)	(B)	1	0.9996	0.9996	0.9996	0.9996	0.9996	0.9996
Madrid (MAD)	(B)	1	1	1	1	1	1	1
Munich (MUC)	(B)	1	1	1	1	1	1	1
Bangkok (BKK)	(B)	1	1	1	1	1	1	1
Beijing (PEK)	(B)	1	1	1	1	1	1	1
Guangzhou (CAN)	(B)	1	1	1	1	1	1	1
Hong Kong (HKG)	(B)	1	1	1	1	1	1	1
Incheon (ICN)	(B)	0.9418	0.9944	0.9944	0.9944	0.9944	0.9944	0.9944
Kuala Lumpur (KUL)	(B)	0.8975	0.8975	0.8975	0.8975	0.8975	0.8975	0.8975
Osaka (KIX)	(B)	1	1	1	1	1	1	1
Tokyo (HRT)	(B)	1	1	1	1	1	1	1
Shanghai (PVG)	(B)	1	1	1	1	1	1	1
Singapore (SIN)	(B)	**0.8318**	**0.6672**	**0.6672**	**0.6672**	**0.6672**	**0.6672**	**0.6672**
Shenzhen (SZX)	(B)	1	1	1	1	1	1	1
Mean		0.9781	0.9706	0.9706	0.9706	0.9706	0.9706	0.9706
S.D.		0.0500	0.0880	0.0880	0.0880	0.0880	0.0880	0.0880

*(A) represents privately operated airports; (B) represents publicly operated airports.

6.4.3 RELATIVE EFFICIENCY ANALYSIS: VS II

VS II is conducted and discussed in this section in order to determine the sensitivity analysis. An examination of VS II (as shown in Table 6.25) reveals that 12 of the 24 airports are operated relatively inefficiently when using the BCC model and the AHP/DEA models to calculate airport efficiency. A number of points emerge from Table 6.25 and Table 6.26, including:

(1) The number of efficient airports is the same as that of inefficient airports (not only in the BCC model but also in all AHP/DEA models).

(2) The efficiency scores between European airports and Asian airports are very close. The average efficiency of Asian airports in the BCC model is 0.8791, and the average efficiency of European airports is 0.8960. In the AHP/DEA model, the average efficiency of Asian airports is 0.8560, and the average efficiency of European airports is 0.8385.

(3) The situation occurring in the AHP analysis is not discovered in Table 6.25, which is that when conducting alternative scales, the weights in scales 1 to 3 are close, and weights in scales 4-6 are also close.

(4) Among these inefficient airports, the efficiency scores of Paris (ORY) (0.4810 in the BCC model, 0.4405 in the AHP/DEA model) and Singapore (0.4580 in the BCC model, 0.4294 in the AHP/DEA model) are relatively smaller than those of other airports.

(5) The efficiency scores between the BCC model and the AHP/DEA model (1-9 scale) are significantly different; for example, the MUC (from 0.9031 to 0.5153) and FCO (from 0.7629 to 0.6711). However, the scores that are calculated using different judgement scales do not obviously change.

(6) The results in VS II can obviously provide a better discriminatory power than VS I.

(7) The results shown in Table 6.26 indicate that when using the BCC model, public airports can achieve better efficiency. However, when conducting the integrated AHP/DEA model, the results show that privately operated airports can get higher efficiency as compared to those that are public by conducting six different scales. However, the difference is only slight. In general, only Singapore (SIN) and Paris (ORY) get relative lower efficiency scores, and the efficiency of the other airports is are higher.

Table: 6.25: Efficiency scores obtained using the AHP/DEA model: VS II

DMU	BCC	1-9	e^{1-9}	2^{1-9}	9/9-9/1	10/10-18/2	∅ mapping
Europe							
Amsterdam (AMS)	0.9010	0.8460	0.8460	0.8460	0.8460	0.8460	0.8460
Barcelona (BCN)	1	1	1	1	1	1	1
Frankfurt (FRA)	0.9996	0.9115	0.9115	0.9115	0.9115	0.9115	0.9115
Istanbul (IST)	0.7046	0.6776	0.6773	0.6773	0.6773	0.6773	0.6773
London (LGW)	1	1	1	1	1	1	1
London (LHR)	1	1	1	1	1	1	1
Madrid (MAD)	1	1	1	1	1	1	1
Munich (MUC)	0.9031	0.5153	0.5153	0.5153	0.5153	0.5153	0.5153
Paris (CDG)	1	1	1	1	1	1	1
Paris (ORY)	**0.4810**	**0.4405**	**0.4405**	**0.4405**	**0.4405**	**0.4405**	**0.4405**
Rome (FCO)	0.7629	0.6711	0.6711	0.6711	0.6711	0.6711	0.6711
Zurich (ZRH)	1	1	1	1	1	1	1
Mean	0.8960	0.8385	0.8385	0.8385	0.8385	0.8385	0.8385
Asia-Pacific							
Bangkok (BKK)	0.8229	0.8212	0.8212	0.8212	0.8212	0.8212	0.8212
Beijing (PEK)	1	1	1	1	1	1	1
Guangzhou (CAN)	0.7039	0.7355	0.7355	0.7355	0.7355	0.7355	0.7355
Hong Kong (HKG)	1	1	1	1	1	1	1
Incheon (ICN)	0.9061	0.9061	0.9061	0.9061	0.9061	0.9061	0.9061
Kuala Lumpur (KUL)	0.6493	0.6137	0.6137	0.6137	0.6137	0.6137	0.6137
Osaka (KIX)	1	1	1	1	1	1	1
Tokyo (HRT)	1	1	1	1	1	1	1
Shanghai (PVG)	0.8065	0.7656	0.7656	0.7656	0.7656	0.7656	0.7656
Singapore (SIN)	**0.4579**	**0.4294**	**0.4294**	**0.4294**	**0.4294**	**0.4294**	**0.4294**
Shenzhen (SZX)	1	1	1	1	1	1	1
Sydney (SYD)	1	1	1	1	1	1	1
Mean	0.8622	0.8560	0.8560	0.8560	0.8560	0.8560	0.8560
Mean of all samples	0.8791	0.8472	0.8472	0.8472	0.8472	0.8472	0.8472

Table 6.26: Airport efficiency under different ownership: VS II

DMU	Ownership category*	BCC	1-9	e^{1-9}	2^{1-9}	9/9-9/1	10/10-18/2	Ø mapping
Amsterdam (AMS)	(A)	0.9010	0.8460	0.8460	0.8460	0.8460	0.8460	0.8460
Istanbul (IST)	(A)	0.7046	0.6776	0.6773	0.6773	0.6773	0.6773	0.6773
London (LGW)	(A)	1	1	1	1	1	1	1
London (LHR)	(A)	1	1	1	1	1	1	1
Paris (CDG)	(A)	1	1	1	1	1	1	1
Paris (ORY)	(A)	**0.4810**	**0.4405**	**0.4405**	**0.4405**	**0.4405**	**0.4405**	**0.4405**
Rome (FCO)	(A)	0.7629	0.6711	0.6711	0.6711	0.6711	0.6711	0.6711
Zurich (ZRH)	(A)	1	1	1	1	1	1	1
Sydney (SYD)	(A)	1	1	1	1	1	1	1
Mean		0.8722	0.8484	0.8483	0.8483	0.8483	0.8483	0.8483
S.D		0.1856	0.2067	0.2068	0.2068	0.2068	0.2068	0.2068
Barcelona (BCN)	(B)	1	1	1	1	1	1	1
Frankfurt (FRA)	(B)	0.9996	0.9115	0.9115	0.9115	0.9115	0.9115	0.9115
Madrid (MAD)	(B)	1	1	1	1	1	1	1
Munich (MUC)	(B)	0.9031	0.5153	0.5153	0.5153	0.5153	0.5153	0.5153
Bangkok (BKK)	(B)	0.8229	0.8212	0.8212	0.8212	0.8212	0.8212	0.8212
Beijing (PEK)	(B)	1	1	1	1	1	1	1
Guangzhou (CAN)	(B)	0.7039	0.7355	0.7355	0.7355	0.7355	0.7355	0.7355
Hong Kong (HKG)	(B)	1	1	1	1	1	1	1
Incheon (ICN)	(B)	0.9061	0.9061	0.9061	0.9061	0.9061	0.9061	0.9061
Kuala Lumpur (KUL)	(B)	0.6493	0.6137	0.6137	0.6137	0.6137	0.6137	0.6137
Osaka (KIX)	(B)	1	1	1	1	1	1	1
Tokyo (HRT)	(B)	1	1	1	1	1	1	1
Shanghai (PVG)	(B)	0.8065	0.7656	0.7656	0.7656	0.7656	0.7656	0.7656
Singapore (SIN)	(B)	**0.4579**	**0.4294**	**0.4294**	**0.4294**	**0.4294**	**0.4294**	**0.4294**
Shenzhen (SZX)	(B)	1	1	1	1	1	1	1
Mean		0.8833	0.8466	0.8466	0.8466	0.8466	0.8466	0.8466
S.D.		0.1663	0.1946	0.1946	0.1946	0.1946	0.1946	0.1946

*(A) represents privately operated airports; (B) represents publicly operated airports.

6.4.4 RELATIVE EFFICIENCY ANALYSIS IN DIFFERENT GROUPS: VS I

As mentioned in Chapter 5 (see Section 5.3), there were two different groups of experts interviewed in this research. In this section, the results of the relative efficient scores are divided into two different groups, those viewed from an academic perspective and those viewed from a practical perspective. An examination of Table 6.27 reveals that, from an academic perspective, 5 of the 24 airports are operated relatively inefficiently, and from a practical perspective, 6 of the 24 airports are operated relatively inefficiently when using an AHP/DEA integrated model that is based on alternative judgement scales to calculate airport efficiency. A number of points emerge from Table 6.27, including:

(1) From both standpoints, there are relatively more efficient airports than inefficient airports.

(2) From both standpoints, in regard to the relative inefficient scores (which are calculated using different scales) it is difficult to determine the differences until the fifth or sixth digit after the decimal point.

(3) The situation occurring in the AHP analysis is not discovered in Table 6.27, which is that when conducting alternative scales, the weights in scales 1 to 3 are close, and weights in scales 4-6 are also close.

(4) The relative efficiency scores between European airports and Asian airports are very close.

(5) From an academic viewpoint, Frankfurt is not an efficient airport but is only slightly lower than Paris (ORY) and Singapore, which have lower efficiency as compared to the results shown from experts from practice.

(6) The efficiency scores and ranks in these two groups are similar to the results shown in Table 6.23.

(7) According to ownership category, in general, the results show that the experts from practice felt that private airports can achieve higher efficiency as compared to those that are public (i.e. 0.9839 vs. 0.9694).

6.4.5 RELATIVE EFFICIENCY ANALYSIS IN A DIFFERENT GROUP: VS II

This section discusses the relative efficiency scores on the basis of VS II in two groups. Table 6.28 reveals that, from both standpoints, 12 of the 24 airports are operated relative inefficiency as shown when conducting the AHP/DEA integrated models that are based on alternative scales to calculate airport efficiency. A number of points emerge from Table 6.28, including:

(1) For both standpoints, there are as many relative efficient airports as there are those that are inefficient.

(2) From both standpoints, in regard to the relative efficiency scores (which are calculated using different scales) it is difficult to determine the differences until the fifth digit after the decimal point.

(3) The situation occurring in the AHP analysis is not discovered in Table 6.28, which is that when conducting alternative scales, the weights in scales 1 to 3 are close, and weights in scales 4-6 are also close.

(4) The relative efficiency scores between European airports and Asian airports are very close.

(5) From an academic viewpoint, Munich, Guangzhou, Shanghai and Singapore have lower efficiency than was expressed by experts from practice. Among these airports, only Singapore has significantly lower efficiency.

(6) The efficiency scores and rank in these two groups are similar to the results shown in Table 6.25.

(7) According to ownership category, in general, the results on both sides show that private airports can achieve higher efficiency than those that are public (i.e. 0.8483 vs. 0.8421 from academia and 0.8849 vs. 0.8532 from practice). The efficiency scores from academia are very close.

Table 6.27: Relative efficiency scores obtained by AHP/DEA model by groups: VS I

	Academia						Practice					
DMU	1-9	e^{1-9}	2^{1-9}	9/9-9/1	10/10-18/2	Ø mapping	1-9	e^{1-9}	2^{1-9}	9/9-9/1	10/10-18/2	Ø mapping
Amsterdam (AMS)	1	1	1	1	1	1	1	1	1	1	1	1
Barcelona (BCN)	1	1	1	1	1	1	1	1	1	1	1	1
Frankfurt (FRA)	0.9992	0.9992	0.9992	0.9992	0.9992	0.9992	1	1	1	1	1	1
Istanbul (IST)	1	1	1	1	1	1	1	1	1	1	1	1
London (LGW)	1	1	1	1	1	1	1	1	1	1	1	1
London (LHR)	1	1	1	1	1	1	1	1	1	1	1	1
Madrid (MAD)	1	1	1	1	1	1	1	1	1	1	1	1
Munich (MUC)	1	1	1	1	1	1	1	1	1	1	1	1
Paris (CDG)	1	1	1	1	1	1	1	1	1	1	1	1
Paris (ORY)	0.655078	0.655073	0.655083	0.655075	0.655073	0.655080	0.855066	0.855096	0.855076	0.855070	0.855084	0.855092
Rome (FCO)	1	1	1	1	1	1	1	1	1	1	1	1
Zurich (ZRH)	1	1	1	1	1	1	1	1	1	1	1	1
Bangkok (BKK)	1	1	1	1	1	1	1	1	1	1	1	1
Beijing (PEK)	1	1	1	1	1	1	1	1	1	1	1	1
Guangzhou (CAN)	1	1	1	1	1	1	1	1	1	1	1	1
Hong Kong (HKG)	1	1	1	1	1	1	1	1	1	1	1	1
Incheon (ICN)	0.941803	0.941805	0.941804	0.941782	0.941805	0.941791	0.941794	0.941804	0.941809	0.941813	0.941812	0.941787
Kuala Lumpur (KUL)	0.897542	0.897542	0.897544	0.897542	0.897542	0.897542	0.897542	0.897542	0.897542	0.897542	0.897541	0.897542
Osaka (KIX)	1	1	1	1	1	1	1	1	1	1	1	1
Tokyo (HRT)	1	1	1	1	1	1	1	1	1	1	1	1
Shanghai (PVG)	1	1	1	1	1	1	1	1	1	1	1	1
Singapore (SIN)	0.631753	0.631762	0.631758	0.631725	0.631762	0.631748	0.701763	0.701790	0.701755	0.701735	0.701736	0.701751
Shenzhen (SZX)	1	1	1	1	1	1	1	1	1	1	1	1
Sydney (SYD)	1	1	1	1	1	1	1	1	1	1	1	1

Table 6.28: Relative efficiency scores obtained by AHP/DEA model by groups: VS II

	Academia						Practice					
DMU	1-9	e^{1-9}	2^{1-9}	9/9-9/1	10/10-18/2	Ø mapping	1-9	e^{1-9}	2^{1-9}	9/9-9/1	10/10-18/2	Ø mapping
Amsterdam (AMS)	0.845978	0.845978	0.845978	0.845978	0.845978	0.845978	0.845978	0.845978	0.845978	0.845978	0.845978	0.845978
Barcelona (BCN)	1	1	1	1	1	1	1	1	1	1	1	1
Frankfurt (FRA)	0.911448	0.911448	0.911448	0.911448	0.911448	0.911448	0.911448	0.911448	0.911448	0.911448	0.911448	0.911448
Istanbul (IST)	0.677262	0.677262	0.677262	0.677262	0.677262	0.677262	0.677262	0.677262	0.677262	0.677262	0.677262	0.677262
London (LGW)	1	1	1	1	1	1	1	1	1	1	1	1
London (LHR)	1	1	1	1	1	1	1	1	1	1	1	1
Madrid (MAD)	1	1	1	1	1	1	1	1	1	1	1	1
Munich (MUC)	0.504758	0.504771	0.504734	0.504779	0.504766	0.504771	0.515271	0.515271	0.515271	0.515271	0.515271	0.515271
Paris (CDG)	1	1	1	1	1	1	1	1	1	1	1	1
Paris (ORY)	0.440539	0.440539	0.440539	0.440539	0.440539	0.440539	0.440539	0.440539	0.440539	0.440539	0.440539	0.440539
Rome (FCO)	0.6711	0.6711	0.6711	0.6711	0.6711	0.6711	0.6711	0.6711	0.6711	0.6711	0.6711	0.6711
Zurich (ZRH)	1	1	1	1	1	1	1	1	1	1	1	1
Bangkok (BKK)	0.821187	0.821187	0.821187	0.821187	0.821187	0.821187	0.821187	0.821187	0.821187	0.821187	0.821187	0.821187
Beijing (PEK)	1	1	1	1	1	1	1	1	1	1	1	1
Guangzhou (CAN)	0.724465	0.724465	0.724465	0.724465	0.724465	0.724465	0.735465	0.735465	0.735465	0.735465	0.735465	0.735465
Hong Kong (HKG)	1	1	1	1	1	1	1	1	1	1	1	1
Incheon (ICN)	0.906072	0.906072	0.906072	0.906072	0.906072	0.906072	0.906072	0.906072	0.906072	0.906072	0.906072	0.906072
Kuala Lumpur (KUL)	0.613665	0.613688	0.613645	0.613633	0.613671	0.613669	0.613687	0.613687	0.613687	0.613687	0.613687	0.613687
Osaka (KIX)	1	1	1	1	1	1	1	1	1	1	1	1
Tokyo (HRT)	1	1	1	1	1	1	1	1	1	1	1	1
Shanghai (PVG)	0.755667	0.755477	0.755762	0.755961	0.755772	0.755884	0.765596	0.765596	0.765596	0.765596	0.765596	0.765596
Singapore (SIN)	**0.339368**	**0.339355**	**0.339367**	**0.339352**	**0.339324**	**0.393345**	**0.529336**	**0.529399**	**0.529357**	**0.529368**	**0.529336**	**0.529347**
Shenzhen (SZX)	1	1	1	1	1	1	1	1	1	1	1	1
Sydney (SYD)	1	1	1	1	1	1	1	1	1	1	1	1
Mean	0.847207	0.847207	0.847207	0.847207	0.847207	0.847207	0.847207	0.847207	0.847207	0.847207	0.847207	0.847207

6.4.6 HYPOTHESIS TESTING: VS I

In this section, after conducting integrated AHP/DEA models, having established the efficiency rankings for the sample airports, a hypothesis related to the rankings obtained needs to be examined. After calculating, the results that were computed using alternative scales are found to be very similar; therefore, only the results calculated using the 1-9 scale are used to test the hypothesis.

Hypothesis: Airports under private management are more efficient than those under public management.

To compare the results easily, the 24 sample airports are classified into two groups: those operate by the public sector and those operated by private companies. There are 15 airports under the public sector (most of them in the Asia-Pacific) and nine airports under private ownership. From Table 6.29, it can be seen that the z-value is −0.798 with a significance level (p) of $p = 0.599$. The probability value (p) is not less than or equal to 0.05, so the result is not significant. There is no statistically significant difference in airport efficiency between privately operated and publicly operated airports as calculated using the integrated AHP/DEA model.

Table 6.29: Mann-Whitney test of differences in efficiency: VS I

Reference	Mann-Whitney *U*-test	Mann-Whitney *Z*-test	Asymptotic significance (two-tailed)
Privately managed airports vs. publicly managed airports	58	−0.798	0.599

6.4.7 Hypothesis testing: VS II

From Table 6.30, the z-value is -0.191 with a significance level (p) of $p = 0.861$. The probability value (p) is not less than or equal to 0.05, so the result is not significant. There is no statistically significant difference in airport efficiency between privately operated and publicly operated airports.

Table 6.30: Mann-Whitney test of differences in efficiency: VS II

Reference	Mann-Whitney *U*-test	Mann-Whitney *Z*-test	Asymptotic significance (two-tailed)
Privately managed airports vs. publicly managed airports	64.5	−0.191	0.861

6.5 CROSS DISCUSSION AND ANALYSIS

Many different analysis procedures and results are described. In this section, cross discussions about efficiency in two variables sets, two different models (basic DEA models and AHP/DEA models), two different groups (academia and practice), and alternative scales in AHP analysis are presented.

6.5.1 DIFFERENT VARIABLE SETS

The most common sensitivity analysis technique in the basic DEA model is to change the numbers of DMUs or the numbers of variables (Cooper et al., 2006). In this research, reducing the numbers of variables is more suitable because the numbers of similar DMUs (airports) are limited in these two regions. Among the sensitivity analysis processes, in the first part, an output-oriented, variable return-to-scale analysis (DEA-BCC model) is used in stepwise modelling for selecting the core DEA variables; however, because of research limitations, only two variables sets are discussed.

Table 6.31 shows the evidence to support the assumption of the DEA method (which states that the number of variables will influence the relative efficiency). Firstly, when the variables were reduced from six inputs and four outputs to three inputs and three outputs, the numbers of inefficient DMUs are shown to increase from five to twelve. Secondly, the average efficiency score decreased from 0.9719 to 0.8791, and the average change is −0.0928. The results from Table 6.31 reveal that a lower number of variables can help to increase the discriminatory power of the DEA model. Furthermore, even when using integrated AHP/DEA models to evaluated airport efficiency, the results are also influenced by the number of variables (see Tables 6.22 and 6.24).

Table: 6.31: A comparison of efficiency scores between the two variable sets

			VS I	VS II
No.	**DMUs**	**Ownership Category**	**BCC Model (VRS)**	**BCC Model (VRS)**
	European			
1	Amsterdam (AMS)	B	1	0.9010
2	Barcelona (BCN)	F	1	1
3	Frankfurt (FRA)	C E	1	0.9996
4	Istanbul (IST)	D	1	0.7046
5	London (LGW)	G	1	1
6	London (LHR)	G	1	1
7	Madrid (MAD)	F	1	1
8	Munich (MUC)	E	1	0.9030
9	Paris (CDG)	B	1	1
10	**Paris (ORY)**	**B**	**0.6551**	**0.4810**
11	Rome (FCO)	B	0.9983	0.7629
12	Zurich (ZRH)	B	1	1
	Asia-Pacific			
13	Bangkok (BKK)	C	1	0.8229
14	Beijing (PEK)	C	1	1
15	Guangzhou (CAN)	C	1	0.7039
16	Hong Kong (HKG)	F	1	1
17	Incheon (ICN)	F	0.9418	0.9061
18	Kuala Lumpur (KUL)	F	0.8975	0.6493
19	Osaka (KIX)	C E	1	1
20	Tokyo (HRT)	F	1	1
21	Shanghai (PVG)	F	1	0.8065
22	Singapore (SIN)	A	0.8318	**0.4579**
23	Shenzhen (SZX)	C	1	1
24	Sydney (SYD)	B	1	1
	Mean		0.9719	0.8791
	S.D		0.0786	0.1698
	Average change in efficiencies			-0.0928
	No. of efficient DMUs		19	12

The reason why the discriminatory power of the result calculated using VS II is higher than that of VS I can be discovered from the weight distribution of variables in Table 6.32.

In the DEA model, the input and output weights are automatically calculated; hence, calculating the relative efficiency using the DEA model will help the DMUs to select these relatively better variables (Kong and Fu, 2012). From Table 6.32, it can be clearly seen that there are many zeros in the weights of inefficient airports for the selected variables in VS I (which is unreasonable when evaluating an airport's peer performance). In VS II, the situation is improved, which means first of all, the number of variables will influence the result when evaluating airport efficiency. Secondly, these variables can place more influence on airport efficiency. With regard to the discriminatory power and the distribution of variable weights, VS II makes the DEA results more accurate and reflects the real decision-making situation of an airport performance evaluation. Consequently, there are still some zero weights in VS II, which means there are still some weaknesses that can be improved upon.

6.5.2 DIFFERENT GROUPS

In contrast to the results shown in Chapter 5, the weights of each variable can be recognised easily when divided into different groups. As shown in Table 5.8, even if the rank of each variable is the same, the weights of each variable vary according to the different groups. In addition, this situation still occurs when using different scales to conduct AHP analysis. As can be seen in Table 5.22, even if the rank of each variable is still the same, the weights of each variable vary according to the different groups. However, after combining the weights with the DEA model, the results do not show the variations obviously, such as is the case with the results shown in Tables 6.27 and 6.28.

Table 6.32: The weight distribution of variables in VS I and VS II

		VS I										VS II					
	DMU	Number of Employees	Number of Gates	Number of Runways	Size of Terminal Area	Length of Runway	Operational Expenditure	Number of Passengers	Amount of Freight and Mails	Aircraft Movements	Total Revenues	Number of Employees	Number of Runways	Size of Terminal Area	Number of Passengers	Amount of Freight and Mails	Aircraft Movements
1	Amsterdam (AMS)	0.1512	0.5355	0	0	0.3134	0	0.0498	0.2374	0.7129	0	0.3068	0	0	0.3068	0	0
2	Barcelona (BCN)	0.4693	0	0	0.5307	0	0	0	0	0	0	0.4693	0	0.5307	0.4693	0	0.5307
3	Frankfurt (FRA)	0	0.3922	0.2917	0	0	0	0	0.1733	0.3918	0.4349	0	0.2924	0	0	0.2924	0
4	Istanbul (IST)	0.3089	0.6911	0	0	0	0	0	0	0	0	0.1984	0	0.0215	0.1984	0	0.0215
5	London (LGW)	0.4086	0	0.5914	0	0	0	0	0	0	0	0.4086	0.5914	0	0.4086	0.5914	0
6	London (LHR)	0	0	0.8145	0.1855	0	0	0	0	0	0	0	0.8145	0.1855	0	0.8145	0.1855
7	Madrid (MAD)	0.4418	0.5582	0	0	0	0	0	0	0	0	0.3636	0.5807	0.0557	0.3636	0.5807	0.0557
8	Munich (MUC)	0	0.2064	0.4127	0	0.2998	0.08116	0	0	0	0	0	0.9949	0	0	0.9949	0
9	Paris (CDG)	0	0.4300	0.5700	0	0	0	0	0	0.9883	0.0117	0.1781	0.1227	0.6532	0.1781	0.1227	0.6532
10	Paris (ORY)	0	0.3477	0	0.53250	0.1228	0.1135	0.0409	0	0.3498	0.6093	0.4224	0.8466	0	0.4224	0.8466	0
11	Rome (FCO)	0	0	0	0.29434	0	0.3600	0.0944	0	0.5061	0.3995	0	0	0.8417	0	0	0.8417
12	Zurich (ZRH)	0.0783	0	0	0.7447	0	0.1769	0.5510	0.3119	0.1371	0	0.2336	0	0.7664	0.2336	0	0.7664
13	Bangkok (BKK)	0	0.2271	0.2269	0.1829	0.2927	0.0703	0	0	0	0	0.3052	0.7732	0	0.3052	0.7732	0
14	Beijing (PEK)	0	0	0.2253	0	0.2813	0.4934	0	0	0	0	0.2155	0.6161	0	0.2155	0.6161	0
15	Guangzhou (CAN)	0	0.1304	0.3136	0.0521	0.3018	0.1767	0.5782	0	0.4218	0	0.4992	0.4762	0.4977	0.4992	0.4762	0.4977
16	Hong Kong (HKG)	0	0.7280	0.2720	0	0	0	0	0	0	0	0.6591	0.3409	0	0.6591	0.3409	0
17	Incheon (ICN)	0	0.8553	0	0	0	0.3714	0	0.3560	0	0.6440	0.3183	0	0.2632	0.3183	0	0.2632
18	Kuala Lumpur (KUL)	0.0677	0	7.2334	0	0	2.2682	0	0	0	0	0.3543	0.8410	0	0.3543	0.8410	0
19	Osaka (KIX)	0.9111	0	0	0.0889	0	0	0	0	0.0114	0.9886	0.4050	0	0.1256	1.4050	0	0.1256
20	Tokyo (HRT)	0.1744	0	0.8256	0	0	0	0	0	0.5303	0.4697	0.0161	0	0	1.0161	0	0
21	Shanghai (PVG)	0	0	0	0	0	0	0.4175	0.5825	0	0	0	0	0	0	0	0
22	Singapore (SIN)	0	0	0	0	0	0.5493	0	0	0	0	0.3565	0.4350	0	0.3565	0.4350	0
23	Shenzhen (SZX)	0	0.5550	0.3435	0.0931	0	0.0084	0	0	0	0	0	0	0.0691	0	0	0.0691
24	Sydney (SYD)	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

6.5.3 ALTERNATIVE JUDGEMENT SCALES IN THE AHP/DEA MODELS

Another sensitivity analysis in this research is carried out by using different analysis models. In this chapter, an integrated AHP/DEA model is applied and also conducted with an alternative scale in AHP analysis.

Tables 6.23 and 6.25 show the efficiency scores calculated using the AHP/DEA-BCC model using alternative scales in two variables sets. The scores reveal that the differences between the BCC model and the AHP/DEA model can be identified easily. However, differences among the alternative scales did not appear. These results are in agreement with those of Jyoti et al. (2008). However, when comparing the scores with those of other scales, the variations are difficult to recognise, even when the number of inefficient DMUs are all the same. In this case, the answer to Research Question 3 is not significant.

There are some reasons why the relative scores are so close when using alternative scales. Firstly, the weight distribution of variables for the AHP/DEA model may cause the results. One could easily find that there are many zero weights for selected variables in these six different scale data sets, which is unreasonable when evaluating an airport's peer performance. This happens because the input and output weights are automatically calculated, which can cause the relative scores to be very close (see the tables attached as Appendix IV). Secondly, it can be seen in Table 6.20 that the weights among the input and output variables are very close in the last column of the value of "Standard Deviation", which brings the weighted data closer (see Appendix III). Therefore, the results for the AHP/DEA models do not accurately reflect the real decision-making situation for airport efficiency evaluation. It is necessary to find another method to assess airport efficiency.

6.6 SUMMARY

This chapter conducted and presented the results of an empirical analysis. The empirical analysis was evaluated by means of different models (from a traditional DEA model (CCR and BCC model) to an integrated AHP/DEA model), different variable sets, (i.e. VS I and VS II), and by using alternative scales in an AHP analysis.

The correlation coefficients analysis shows the variables that were selected in both variable sets to be robust. In addition, the Mann-Whitney test shows that the hypothesis that airports under private management are more efficient than those under public management was not significant in both variables sets. In addition, this research used an integrated AHP/DEA model to evaluate airport efficiency, which was proposed by Jyoti et al. (2008). Using Saaty's 1-9 scale, it can be seen that this AHP/DEA model has provided a fair and useful technique by which to evaluate the performance of airports in terms of their relative efficiencies, not only on the basis of the quality of variables but also based on the integration of diverse viewpoints. However, when introducing alternative scales to the AHP model, the results were not reliable, and the differences were not obvious. Therefore, this kind of calculation method cannot provide realistic results when benchmarking airports.

An AHP/DEA-AR model is conducted in the next chapter in order to prevent impractical variable weights and to verify Research Question 1. The weights of the variables obtained from an AHP survey are passed into the assurance region of the DEA-AR model for empirical analysis. The empirical results can help to increase discriminatory power, and they can also help to overcome the shortcomings of the AHP/DEA model (such as illogical local weights).

CHAPTER 7

AIRPORT EFFICIENCY ANALYSIS II:
AHP/DEA-AR MODEL

Chapter 6 focused on presenting the airport efficiency analysis by means of basic DEA models and integrated AHP/DEA models. However, the discriminatory powers of these models are not good enough. Therefore, in this chapter, by conducting sensitivity analysis, another AHP/DEA-AR model is applied to assess airport efficiency. The concepts and analysis process for the efficiency scores are described in first section. The second and third sections describe the efficiency score computed on VS I and VS II. The fourth section, the results are compared with the DEA-BCC model and integrated AHP/DEA models. Some additional thoughts on airport efficiency analysis are presented in the last section.

7.1 AHP/DEA-AR MODEL

7.1.1 CONCEPTS OF DEA-AR MODEL

Chapter 6 described how the DEA was combined with the AHP to form an AHP/DEA model for weight derivation and aggregation in the AHP, which was used to evaluate airport efficiency; however, these results were not robust. In this chapter, a DEA model with Assurance Region (AR) for priority derivation in the AHP is proposed, which is referred to as the DEA-AR model. This DEA-AR model can help to solve the shortcomings of the AHP/DEA model, such as illogical local weights, over insensitivity to some comparisons, information loss, and overestimation of some local weights. It can also provide a better priority estimate and better decision conclusions than the AHP/DEA model (Wang et al. 2008; Liang and Fang 2011; Kong and Fu 2012). In addition, it can provide the answers to the research questions.

In practice, when conducting efficiency evaluation, DMUs do not always allow the choice of the best variable or place higher weights on particular variables because the best weights choice could result in extreme weight distributions (Doyle and Green 1994). In addition, this course of action is not usually employed in actual airport efficiency assessment practices. Therefore, this study employs the DEA-AR approach that was developed by Thompson et al. (1986) to avoid this unreasonable distribution of weights. The DEA-AR model can allow weights to vary within a range by imposing constraints on the relative magnitudes of the weights for special items. The AR model is used to impose restrictions on the upper bound (U_{ij}) and lower bound (L_{ij}) of a ratio of the weights of two variables (u_i/u_j), as follows:

$$L_{ij} \leq \frac{u_i}{u_j} \leq U_{ij} \ . \tag{1}$$

This research employs the DEA-AR model to reflect the relative importance of input and output variables. Therefore, by adding the constraints in Equation (1) into the BCC model, the DEA-AR-BCC model (DEA-AR model in short) can be obtained. However, the question of how the lower and upper bounds are determined needs to be addressed. Some studies determine the lower and upper bounds based on the weight analysis of a DEA model (Thompson et al. 1986), and some studies determine them based on expert opinions (such as, Zhu 1996; Seifert and Zhu 1998; Takamura and Tone 2003) a notable example of this being the AHP.

7.1.2 LITERATURE FOR THE DEA-AR MODEL AND THE AHP/DEA-AR MODEL

In an early study, the DEA-AR model was used to evaluate the efficiency of 83 farms in Kansas (Thompson et al. 1990). After conducting the DEA-AR model, Thompson et al. (1990) were able to reduce the number of efficient DMUs from 23 to 8. Their results revealed that the DEA-AR model could provide more accurate efficiency scores than traditional DEA models. Taylor et al. (1997) used DEA and Linked-Cone Assurance Region (LC-AR) models to investigate the efficiency and profitability potential of Mexican banks as they engaged in activities that incurred interest and non-interest expenses and produced income. In addition, Lee et al. (2009) employed three DEA models (i.e. DEA-BCC model, the DEA-AR model, and output integration) to measure and compare the performance of national research and development programs. The results provided policy implications for effectively formulating and implementing national research and development programs. Traditional DEA models and Additive-AR models were used by Liang and Fang (2011) to evaluate the productivity and quality performance of TFT-LCD suppliers. Their results were valuable in terms of optimising the selection of an appropriate supplier for the TFT-LCD company. These previous studies reveal that the DEA-AR model can help improve the accuracy of efficiency evaluation although they were not conducted in the context of air transport.

Similarly, the model combining the AHP and DEA-AR model has been previously employed in other fields of studies. For example, the AHP/DEA-AR model was first used in a study that evaluated the performance of the Nanjing Textiles Corporation (Zhu 1996). Seifert and Zhu (1998) used this model to investigate excess and deficits in regard to Chinese industrial productivity for the years 1953-1990 and found that the weights of ARs could be obtained through expert opinions using the Delphi and AHP approaches.

Several applications of the AHP/DEA-AR model can also be found for the public sector. For example, Takamura and Tone (2003) used the AHP/DEA-AR model to provide two possible locations to relocate Japanese government agencies out of Tokyo. Meanwhile, Meng et al. (2008) combined AHP, AR, and a two-level DEA to evaluate the research performance of research institutes in the Chinese Academy of Sciences. Finally, Wang et al. (2008) proposed a DEA model with AR for priority derivation in the AHP, which is referred to as the DEA-AR model.

7.1.3 AHP/DEA-AR MODEL IN THIS RESEARCH

In this research, the AHP/DEA-AR model is applied to evaluate the efficiency of airports in both Europe and the Asia-Pacific regions. This approach can make contributions to the literature in the following two aspects: Firstly, an AHP survey is conducted with airport managers and researchers to derive the upper and lower bounds of weight restrictions of the ARs. All the variables are pre-selected by a representative literature review of airport efficiency studies over the last 20 years. The reliability is also increased by means of interviews with a number of industry experts. Secondly, and perhaps the most important contribution of this research, is the fact that this is the first study that has proposed to use the AHP/DEA-AR model to assess airport efficiency. That is, instead of assessing airport efficiency from the perspective of airport operators, the weights of the variables are considered from two different vewpoints (i.e. practice and academia). The process for conducting the AHP/DEA-AR model in this research is described below.

As mentioned in previous chapters, a total of 35 questionnaires were sent out, and a total of 25 completed questionnaires were collected. The weight of each variable was calculated from the answers of the respondents. The calculations were conducted using Super Decision, which is a dedicated AHP software program. The results were then cross checked using the Maple 14 software program. The reliability of the weights was considered acceptable if the consistency in the respondent's questionnaire, or the Consistency Index (CI), < 0.1. Where the CI was not considered acceptable, the questionnaires were excluded from the effective responses. In this research, an effective rate of 62.86% was achieved for 22 acceptable questionnaires. The main difference between the AHP/DEA model and the AHP/DEA-AR model is the method by which the AHP result is derived. When conducting the AHP/DEA model, the geometric mean method was used to solve the eigenvalue of pair-wise comparison matrix, which was in turn used to calculate the local weight of each level on a spread-sheet (Saaty 2003). When conducting AHP/DEA-AR model, the preference of each respondent was needed to calculate the individual results (Kong and Fu 2012).

7.2 AIRPORT EFFICIENCY ANALYSIS: VS I

As mentioned in Chapter 6, two different variable sets are adopted with the AHP/DEA-AR model. VS I (which includes ten variables) is conducted to evaluate airport performance in this section.

7.2.1 BOUNDS CALCULATION

When conducting the AHP/DEA-AR model, the weights of each variable are displayed by each respondent. The results derived from AHP analysis are then used as a guideline for setting the upper and lower bounds. The respondents' derived weights attached to the input and output variables of performance are shown in Table 7.1. Respondents 1 to 15 are drawn from practice while respondents 16 to 22 come from academia. From the weight averages of these two groups, the respondents from practice are found to relatively place more emphasis on the financial variables than on other variables ($WI6$: Operational expenditure and $WO4$: Total revenue). This result is similar to common opinion because, generally speaking, an airport authority should concentrate more on financial variables.

The results derived from the AHP analysis then served as a guideline for setting the upper and lower bounds in the AHP/DEA-AR model. To incorporate these weights in DEA-AR model, pair-wise divisions between the weights were made. The largest and smallest values of each weight ratio for all respondents were then found, and the upper and lower bounds values of this weight ratio were then constructed. For example, for Respondent 11 (as shown in Table 7.1) the ratio WI_1/WI_2 takes on a value of $0.0646/0.0238$. The ratio WI_1/WI_2 for the other 21 respondents can be calculated by this order. Therefore, the highest WI_1/WI_2 =2.7143 from Respondent 11 is used as the upper bound of the ratio WI_1/WI_2, and the smallest WI_1/WI_2 is 0.0765 from Respondent 2 is used as the lower bound. Therefore, the range of WI_1/WI_2 is 0.0765 $\leq WI_1/WI_2 \leq$ 2.7143. This ratio weight inequality constraint is then incorporated into the AHP/DEA-AR model. Other ranges (or upper and lower bounds) of ratio weights can be found in Table 7.2. The upper and lower bounds that are addressed by the AHP alternative scales are listed in Appendix IV.

Table 7.1: AHP weights of input and output variables of respondents (1-9 scale)

Input Variables							Output Variables			
Variables	Number of Employees	Number of Gates	Number of Runways	Size of Terminal Area	Length of Runway	Operational Expenditure	Number of Passengers	Amount of Freight and Mails	Aircraft Movements	Total Revenues
Respondent	*WI1*	*WI2*	*WI3*	*WI4*	*WI5*	*WI6*	*WO1*	*WO2*	*WO3*	*WO4*
1	0.0113	0.0697	0.0661	0.0755	0.0275	0.7500	0.0632	0.0505	0.0113	0.875
2	0.0046	0.0601	0.0252	0.0382	0.0148	0.8571	0.1118	0.0704	0.0177	0.8000
3	0.0205	0.2157	0.099	0.1368	0.0281	0.5000	0.0667	0.0667	0.0095	0.8571
4	0.0103	0.0952	0.0389	0.0899	0.0158	0.7500	0.2222	0.2222	0.0556	0.5000
5	0.0056	0.0627	0.0302	0.0543	0.0139	0.8333	0.2273	0.2273	0.0455	0.5000
6	0.0063	0.0641	0.0288	0.0518	0.0157	0.8333	0.0857	0.0857	0.0286	0.8000
7	0.0058	0.0669	0.0242	0.0148	0.0551	0.8333	0.1062	0.043	0.0175	0.8333
8	0.0308	0.1803	0.2993	0.2303	0.0925	0.1667	0.3815	0.3468	0.105	0.1667
9	0.0318	0.205	0.0744	0.3522	0.1699	0.1667	0.0912	0.0574	0.0181	0.8333
10	0.005	0.0385	0.0329	0.0531	0.0133	0.8571	0.6086	0.2004	0.066	0.1250
11	0.0646	0.0238	0.0155	0.0201	0.0189	0.8571	0.0416	0.0262	0.1322	0.8000
12	0.0332	0.0189	0.1016	0.0125	0.0337	0.8000	0.3304	0.1041	0.0656	0.5000
13	0.0257	0.3525	0.1152	0.0769	0.2297	0.2000	0.3185	0.1291	0.0524	0.5000
14	0.0269	0.2047	0.4294	0.0558	0.1164	0.1667	0.3694	0.141	0.3229	0.1667
15	0.0129	0.0785	0.0371	0.0345	0.0371	0.8000	0.4405	0.1388	0.0874	0.3333
Average	***0.0197***	***0.1158***	***0.0945***	***0.0864***	***0.0588***	***0.6248***	***0.2310***	***0.1273***	***0.0690***	***0.5727***
16	0.1898	0.1421	0.2201	0.1604	0.1209	0.1667	0.0781	0.3293	0.0926	0.5
17	0.0067	0.0538	0.0226	0.0592	0.0244	0.8333	0.3704	0.3704	0.0926	0.1667
18	0.0179	0.1004	0.0823	0.2445	0.0549	0.5000	0.5269	0.2102	0.0629	0.200
19	0.0099	0.0577	0.0757	0.079	0.0277	0.7500	0.3030	0.3030	0.0606	0.3333
20	0.0134	0.1041	0.0284	0.0839	0.0202	0.7500	0.4700	0.0702	0.2098	0.2500
21	0.031	0.1641	0.314	0.1525	0.1717	0.1667	0.3467	0.3815	0.1050	0.1667
22	0.0207	0.0392	0.0675	0.0198	0.0195	0.8333	0.1071	0.0357	0.1071	0.7500
Average	***0.0413***	***0.0945***	***0.1158***	***0.1142***	***0.0628***	***0.5714***	***0.3146***	***0.2429***	***0.1044***	***0.3381***
Average in Total	***0.0266***	***0.1090***	***0.1013***	***0.0953***	***0.0601***	***0.6078***	***0.2576***	***0.1641***	***0.0803***	***0.4981***

Table 7.2: Upper and lower bounds of variable weight ratios (1-9 scale)

Input Weight Ratio	Upper	Lower	Output Weight Ratio	Upper	Lower
WI1/WI2	2.7143	0.0765	*WO1/WO2*	6.6952	0.2372
WI1/WI3	4.1677	0.0626	*WO1/WO3*	9.2212	0.3147
WI1/WI4	3.2139	0.0732	*WO1/WO4*	4.8688	0.0722
WI1/WI5	3.4180	0.1053	*WO2/WO3*	7.0211	0.3333
WI1/WI6	1.1386	0.0054	*WO2/WO4*	2.2885	0.0476
WI2/WI3	3.6655	0.4767	*WO3/WO4*	1.9370	0.0111
WI2/WI4	4.5839	0.4106			
WI2/WI5	7.6762	0.5608			
WI2/WI6	1.7625	0.0236			
WI3/WI4	8.1280	0.2112			
WI3/WI5	3.6890	0.4392			
WI3/WI6	2.5759	0.0181			
WI4/WI5	5.6899	0.2686			
WI4/WI6	2.1128	0.0156			
WI5/WI6	1.1485	0.0173			

7.2.2 RELATIVE EFFICIENCY ANALYSIS

The results of the DEA-BCC model, the AHP/DEA model, and the proposed AHP/DEA-AR are summarised in Table 7.3. It can be seen there are eight evaluation items for airport efficiency. The first column presents the efficiency scores, which are calculated using the original DEA-BCC model. The second column shows the efficiency scores, which are calculated using the AHP/DEA model, and the weights of each variable are considered using a 1-9 scale. The third column shows the efficiency scores calculated using the DEA-AR model, and the weights of each variable are considered using a 1-9 scale. Columns four to eight reveal the efficiency scores, which are computed by the weights of each variable considered in the alternative scales.

An examination of VS I reveals that 5 of the 24 airports are operated relatively inefficiently when using the BCC model and the integrated AHP/DEA model to calculate airport efficiency, and the number of efficient airports are quite varied in the AHP/DEA-AR model. The following points have been developed from this table:

(1) The number of relatively efficient airports is found to be less than that of those that are inefficient by means of the AHP/DEA-AR model.

(2) The reason for the use of alternative scales is to transform the AHP questionnaire into numerical scales more accurately. The result shows that in the proposed

AHP/DEA-AR model, different scales provide different numbers of efficient airports.

(3) The Standard Deviation (S.D.) of the efficiency score for the entire sample in the DEA-BCC model is 0.0783, and in the AHP/DEA model, it is 0.0773. Whereas, the S.D. is from 0.1862, which is calculated by scale 2^{1-9} to 0.2445, which is calculated from scale $\emptyset$ mapping in the proposed AHP/DEA-AR model. Therefore, these relative efficiency scores and S.D. indicate that the proposed AHP/DEA-AR model possesses better discriminatory power than the DEA-BCC model and the AHP/DEA model.

(4) The results from the proposed model show that the mean of efficiency scores for the whole sample in the 1-9 scale is 0.7231 (see Table 7.3), whereas the average efficiency scores for European airports is 0.7669, and for Asia-Pacific airports is 0.6794. Generally speaking, the efficiency of European airports is better than those of the Asia-Pacific region. Furthermore, it is worth noting that some Asian airports are performing well; for example, Hong Kong and Shenzhen are performing better than many European airports. However, Singapore Airport only achieved an efficiency score of 0.2471 among the 24 airports under consideration. The most reasonable explanation for this is that Singapore Airport has the second largest terminal area size (1,043,020 m^2) (see Table 6.2), but its output performance is much lower, being ranked 21st for number of passengers, 17th for amount of freight, 23rd for aircraft movements, and 11th for total revenue. This explains why Singapore Airport did not achieve higher efficiency scores through the DEA analysis. Potential root causes for the efficiency score include management performance objectives that place a greater emphasis on passenger experience and the introduction of additional terminal capacity. Consequently, although in the short term, Singapore Airport is under-utilised, it allows for passenger number growth in the long term.

(5) Among those efficiency scores which were calculated using the AHP/DEA-AR model, the S.D. value shows that ø mapping scale can provide more discriminatory power (i.e. 0.2445). It also shows that the AHP/DEA-AR model can also provide higher discriminatory power than either the DEA-BCC model or the AHP/DEA model.

(6) The results shown in Table 7.4 reveal that when applying the BCC model, public airports can achieve better efficiency, but using the AHP/DEA model, private airports can achieve higher efficiency than those that are public. In addition, when applying the AHP/DEA-AR model, the results show that privately operated airports can get higher efficiency than public ones by conducting six different scales.

(7) Another benefit of using the AHP/DEA-AR model is to avoid extreme weight distribution. The weight distribution of output variables for the DEA model is shown in Table 7.5. Because the output oriented DEA-BCC model is applied in this research, only output variable distribution needs to be discussed herein. (Cooper et al., 2006). From Table 7.5, it can be seen that there are many zero weights for the selected output variables, which is unreasonable when evaluating airport peer performance. Such an unreasonable situation is not found to exist in the proposed DEA-AR model, in which all of the output weights are larger than zero. That implies when using AHP/DEA-AR model to assess airport efficiency, all the output variables are considered. If comparing the weight distribution of variables with the integrated AHP/DEA model, the result is once again much better than that obtained when using the integrated AHP/DEA model.

In regard to the discriminatory power and the distribution of variables weights, the proposed AHP/DEA-AR model makes the DEA results more accurate and able to reflect the real decision-making situation for airport performance evaluation. Consequently, in this research, the AHP/DEA-AR model is found to achieve better results than either the traditional DEA model or the integrated AHP/DEA model.

Table 7.3: Efficiency scores obtained using the AHP/DEA-AR model: VS I

DMU	DEA BCC Model	AHP/DEA model	DEA-AR Model					
			1	2	3	4	5	6
		1-9	1-9	e^{1-9}	2^{1-9}	9/9-9/1	10/10-18/2	∅ mapping
European								
Amsterdam (AMS)	1	1	0.7589	0.7876	0.7933	0.6924	0.7180	0.6862
Barcelona (BCN)	1	1	0.9088	1	1	0.7027	0.7633	0.6856
Frankfurt (FRA)	1	0.9996	0.8574	0.9412	0.9509	0.7538	0.7842	0.7462
Istanbul (IST)	1	1	0.7360	0.7715	0.8484	0.6356	0.6495	0.6296
London (LGW)	1	1	0.6167	0.6879	0.7341	0.4660	0.5092	0.4539
London (LHR)	1	1	1	1	1	1	1	1
Madrid (MAD)	1	1	0.8645	0.9761	1	0.6276	0.6871	0.6109
Munich (MUC)	1	1	0.4965	0.5901	0.6798	0.3666	0.4095	0.3555
Paris (CDG)	1	1	1	1	1	0.9530	0.9789	0.9467
Paris (ORY)	0.6551	0.8205	0.3541	0.4184	0.4734	0.2408	0.2676	0.2332
Rome (FCO)	0.9983	1	0.6094	0.7208	0.7822	0.4224	0.4714	0.4088
Zurich (ZRH)	1	1	1	1	1	1	1	1
Mean	0.9711	0.9850	0.7669	0.8245	0.8552	0.6551	0.6866	0.6464
Asia								
Bangkok (BKK)	1	1	0.6436	0.6689	0.7590	0.5756	0.5923	0.5709
Beijing (PEK)	1	1	0.6579	0.7460	0.7660	0.5420	0.5746	0.5343
Guangzhou (CAN)	1	1	0.7168	0.7620	0.8603	0.6048	0.6204	0.5986
Hong Kong (HKG)	1	1	1	1	1	1	1	1
Incheon (ICN)	0.9418	0.9944	0.8531	0.8548	0.8555	0.8488	0.8500	0.8477
Kuala Lumpur (KUL)	0.8975	0.8975	0.4379	0.4630	0.5418	0.3723	0.3842	0.3685
Osaka (KIX)	1	1	0.5923	0.6036	0.6138	0.5777	0.5800	0.5766
Tokyo (HRT)	1	1	0.6343	0.6417	0.6650	0.6256	0.6274	0.6247
Shanghai (PVG)	1	1	0.7907	0.8032	0.8046	0.7787	0.7822	0.7778
Singapore (SIN)	0.8318	**0.6672**	0.2471	0.2916	0.3135	0.1905	0.2063	0.1865
Shenzhen (SZX)	1	1	1	1	1	1	1	1
Sydney (SYD)	1	1	0.5793	0.6518	0.7774	0.4296	0.4572	0.4208
Mean	0.9726	0.9633	0.6794	0.7072	0.7464	0.6288	0.6396	0.6255
Mean of all samples	0.9719	0.9741	0.7231	0.7658	0.8008	0.6419	0.6631	0.6360
S.D.	0.0786	0.0773	0.2141	0.2037	0.1862	0.2421	0.2344	0.2445

Table 7.4: Airport efficiency with different ownership: VS I

DMU	Ownership category*	BCC	AHP/DEA model	AHP/DEA-AR					
				1-9	e^{1-9}	2^{1-9}	9/9-9/1	10/10-18/2	$\emptyset$ mapping
Amsterdam (AMS)	(A)	1	1	0.7589	0.7876	0.7933	0.6924	0.718	0.6862
Istanbul (IST)	(A)	1	1	0.736	0.7715	0.8484	0.6356	0.6495	0.6296
London (LGW)	(A)	1	1	0.6167	0.6879	0.7341	0.466	0.5092	0.4539
London (LHR)	(A)	1	1	1	1	1	1	1	1
Paris (CDG)	(A)	1	1	1	1	1	0.953	0.9789	0.9467
Paris (ORY)	(A)	0.6551	0.8205	0.3541	0.4184	0.4734	0.2408	0.2676	0.2332
Rome (FCO)	(A)	0.9983	1	0.6094	0.7208	0.7822	0.4224	0.4714	0.4088
Zurich (ZRH)	(A)	1	1	1	1	1	1	1	1
Sydney (SYD)	(A)	1	1	0.5793	0.6518	0.7774	0.4296	0.4572	0.4208
Mean		0.9615	0.9801	0.7394	0.7820	0.8232	0.6489	0.6724	0.6421
S.D		0.1149	0.0598	0.2264	0.1951	0.1693	0.2829	0.2712	0.2866
Barcelona (BCN)	(B)	1	1	0.9088	1	1	0.7027	0.7633	0.6856
Frankfurt (FRA)	(B)	1	0.9996	0.8574	0.9412	0.9509	0.7538	0.7842	0.7462
Madrid (MAD)	(B)	1	1	0.8645	0.9761	1	0.6276	0.6871	0.6109
Munich (MUC)	(B)	1	1	0.4965	0.5901	0.6798	0.3666	0.4095	0.3555
Bangkok (BKK)	(B)	1	1	0.6436	0.6689	0.759	0.5756	0.5923	0.5709
Beijing (PEK)	(B)	1	1	0.6579	0.746	0.766	0.542	0.5746	0.5343
Guangzhou (CAN)	(B)	1	1	0.7168	0.762	0.8603	0.6048	0.6204	0.5986
Hong Kong (HKG)	(B)	1	1	1	1	1	1	1	1
Incheon (ICN)	(B)	0.9418	0.9944	0.8531	0.8548	0.8555	0.8488	0.85	0.8477
Kuala Lumpur (KUL)	(B)	0.8975	0.8975	0.4379	0.463	0.5418	0.3723	0.3842	0.3685
Osaka (KIX)	(B)	1	1	0.5923	0.6036	0.6138	0.5777	0.58	0.5766
Tokyo (HRT)	(B)	1	1	0.6343	0.6417	0.665	0.6256	0.6274	0.6247
Shanghai (PVG)	(B)	1	1	0.7907	0.8032	0.8046	0.7787	0.7822	0.7778
Singapore (SIN)	**(B)**	**0.8318**	**0.6672**	**0.2471**	**0.2916**	**0.3135**	**0.1905**	**0.2063**	**0.1865**
Shenzhen (SZX)	(B)	1	1	1	1	1	1	1	1
Mean		0.9781	0.9706	0.7134	0.7561	0.7873	0.6378	0.6574	0.6323
S.D.		0.0500	0.0880	0.2139	0.2149	0.2001	0.2246	0.2195	0.2263

*(A) represents privately operated airports; (B) represents publicly operated airports.

Table 7.5: The weight distribution of output variables: VSI

	BCC model				AHP/DEA-AR model			
DMUs	Wo1	Wo2	Wo3	Wo4	Wo1	Wo2	Wo3	Wo4
1	0.0498	0.2374	0.7129	0	0.0974	0.4810	0.4112	0.0103
2	1	0	0	0	0.1591	0.0820	0.7586	0.0004
3	0	0.1733	0.3918	0.4349	0.0902	0.5317	0.3671	0.0111
4	1	0	0	0	0.1236	0.4956	0.3806	0.0003
5	1	0	0	0	0.1991	0.0977	0.6876	0.0156
6	1	0	0	0	0.1253	0.7766	0.0970	0.0011
7	1	0	0	0	0.1637	0.1582	0.6777	0.0005
8	0	0	1	0	0.1263	0.1499	0.7081	0.0157
9	0	0	0.9883	0.0117	0.1029	0.5503	0.3463	0.0006
10	0.0409	0	0.3498	0.6093	0.1736	0.1385	0.6831	0.0048
11	0.0944	0	0.5061	0.3995	0.1667	0.0971	0.7351	0.0010
12	0.5510	0.3119	0.1371	0	0.1166	0.3054	0.5771	0.0009
13	1	0	0	0	0.1347	0.5539	0.3109	0.0004
14	1	0	0	0	0.1235	0.4511	0.4251	0.0003
15	0.5782	0	0.4218	0	0.1278	0.3916	0.4803	0.0003
16	1	0	0	0	0.0284	0.9523	0.0191	0.0001
17	0	0.3560	0	0.6440	0.0029	0.9836	0.0122	0.0013
18	1	0	0	0	0.1358	0.4988	0.3651	0.0003
19	0	0	0.0114	0.9886	0.0250	0.8708	0.0835	0.0207
20	0	0	0.5303	0.4697	0.0744	0.7150	0.1975	0.0131
21	0.4175	0.5825	0	0	0.0078	0.7594	0.2326	0.0002
22	0	0	0	1	0.1339	0.3633	0.4859	0.0169
23	1	0	0	0	0.0590	0.7348	0.2061	0.0001
24	1	0	0	0	0.1383	0.2952	0.5633	0.0032

7.2.3 RELATIVE EFFICIENCY ANALYSIS IN DIFFERENT GROUPS

This section discusses the efficiency scores on the basis of VS I in two groups, from an academic standpoint and a practical standpoint. Table 7.6 reveals that, from both standpoints, relatively efficient airports are pointed out when conducting an AHP/DEA-AR model based on alternative scales. A number of points emerge from Table 7.6, including:

(1) From both standpoints, in the relatively inefficient airports (which are calculated using different scales) it is easy to recognise the differences.

(2) The situation occurring in AHP analysis is not discovered in Table 6.27, which is that when conducting alternative scales, the weights in scales 1 to 3 are close, and weights in scales 4-6 are also close.

(3) The efficient airports are slightly different from academic viewpoints and practical viewpoints. Among inefficient airports, only Singapore and Paris (ORY) have significant lower efficiency scores.

(4) The efficiency scores and rankings of these two groups are similar to the results shown in Table 7.6.

Table: 7.6: Relative efficiency scores obtained using the AHP/DEA-AR model by groups: VS I

	Academia						Practice					
DMU	1-9	e^{1-9}	2^{1-9}	9/9-9/1	10/10-18/2	∅ mapping	1-9	e^{1-9}	2^{1-9}	9/9-9/1	10/10-18/2	∅ mapping
Amsterdam (AMS)	0.6204	0.6226	0.6342	0.6402	0.6335	0.6411	0.7552	0.7491	0.7926	0.6921	0.6879	0.6715
Barcelona (BCN)	0.4217	0.4218	0.4433	0.5056	0.4769	0.5107	0.8799	0.8733	1	0.7024	0.6944	0.6401
Frankfurt (FRA)	0.6780	0.6850	0.7144	0.6958	0.6892	0.6963	0.8470	0.8300	0.9474	0.7531	0.7477	0.7290
Istanbul (IST)	0.5981	0.5999	0.6138	0.6140	0.6076	0.6150	0.7282	0.7436	0.8600	0.6353	0.6466	0.6281
London (LGW)	0.3178	0.3297	0.3832	0.3506	0.3368	0.3521	0.5866	0.5712	0.7320	0.4656	0.4575	0.4225
London (LHR)	1	1	1	1	1	1	1	1	1	1	1	1
Madrid (MAD)	0.4336	0.4333	0.4463	0.4908	0.4705	0.4941	0.8331	0.8132	1	0.6276	0.6254	0.5766
Munich (MUC)	0.2376	0.2435	0.2699	0.2749	0.2623	0.2762	0.4940	0.4789	0.6788	0.3661	0.3602	0.3304
Paris (CDG)	0.8739	0.8727	0.8715	0.8985	0.8907	0.8997	1	1	1	0.9529	0.9489	0.9319
Paris (ORY)	0.1652	0.1711	0.1980	0.1856	0.1776	0.1863	0.3418	0.3341	0.4754	0.2406	0.2400	0.2188
Rome (FCO)	0.2667	0.2753	0.3164	0.3102	0.2942	0.3120	0.5936	0.5768	0.7806	0.4223	0.4187	0.3793
Zurich (ZRH)	1	1	1	1	1	1	1	1	1	1	1	1
Bangkok (BKK)	0.5354	0.5370	0.5464	0.5453	0.5412	0.5456	0.6314	0.6400	0.7643	0.5756	0.5749	0.5622
Beijing (PEK)	0.4622	0.4616	0.4650	0.4809	0.4740	0.4819	0.6373	0.6200	0.7660	0.5420	0.5353	0.5159
Guangzhou (CAN)	0.5510	0.5510	0.5570	0.5734	0.5653	0.5744	0.7116	0.7192	0.8664	0.6048	0.6147	0.5940
Hong Kong (HKG)	1	1	1	1	1	1	1	1	1	1	1	1
Incheon (ICN)	0.8478	0.8507	0.8555	0.8470	0.8476	0.8463	0.8500	0.8502	0.8577	0.8471	0.8460	0.8447
Kuala Lumpur (KUL)	0.3385	0.3395	0.3483	0.3491	0.3448	0.3497	0.4311	0.4374	0.5479	0.3723	0.3749	0.3635
Osaka (KIX)	0.5749	0.5848	0.6136	0.5729	0.5730	0.5727	0.5868	0.5884	0.6295	0.5768	0.5775	0.5754
Tokyo (HRT)	0.6271	0.6344	0.6612	0.6235	0.6240	0.6229	0.6323	0.6309	0.6577	0.6250	0.6247	0.6235
Shanghai (PVG)	0.7633	0.7669	0.7656	0.7713	0.7701	0.7715	0.7860	0.7847	0.8046	0.7787	0.7771	0.7754
Singapore (SIN)	0.1545	0.1589	0.1770	0.1613	0.1584	0.1615	0.2379	0.2292	0.3122	0.1901	0.1870	0.1775
Shenzhen (SZX)	1	1	1	1	1	1	1	1	1	1	1	1
Sydney (SYD)	0.3577	0.3677	0.4218	0.3776	0.3688	0.3786	0.5666	0.5731	0.7967	0.4294	0.4365	0.4101

7.2.4 HYPOTHESIS TESTING

This section describes how, after conducting the AHP/DEA-AR model and having established the efficiency rankings of the sample airports, the hypothesis related to the rankings obtained needs to be tested. However, unlike in Chapter Seven, in this section, all of the results are used to test the hypothesis due to the varying outcomes for the efficiency scores.

Table 7.7 shows that all the significance levels (p) are not less than or equal to 0.05; therefore, the result is not significant. In other words, there is no statistically significant difference in airport efficiency between privately operated and publicly operated airports as calculated using the AHP/DEA-AR model. The main objective of privatisation is to improve efficiency and reduce government involvement in industry (Humphreys, 1999); however, the results in this research are found to be quite different from this main objective. In addition, the results also contrast with those of Barros and Dieke (2007), who found a significantly higher difference in efficiency scores for privately managed airports as compared to those that were publicly managed.

Table 7.7: Mann-Whitney test of differences in efficiency: Variable Set I

Reference	Scale	Mann-Whitney *U*-test	Mann-Whitney *Z*-test	Asymptotic Significance (two-tailed)
Privately managed airports vs. publicly managed airports	1-9	60	-0.449	0.653
	e^{1-9}	60.5	-0.421	0.682
	2^{1-9}	61	-0.392	0.726
	9/9-9/1	66	-0.090	0.953
	10/10-18/2	67	-0.030	1.000
	$\emptyset$ mapping	65	-0.149	0.907

7.3 AIRPORT EFFICIENCY ANALYSIS: VS II

In order to conduct sensitivity analysis, VS II (six variables) is undertaken in this section in order to evaluate airport performance.

7.3.1 BOUNDS CALCULATION

The respondents' derived weights attached to the input and output variables of performance are shown in Table 7.8. The results derived from the AHP analysis serve as a guideline for setting the upper and lower bounds in the AHP/DEA-AR model. This ratio weight inequality constraint is incorporated in the AHP/DEA-AR model. Other ranges (or upper and lower bounds) of ratio weights can be found in Table 7.9. The upper and lower bounds addressed by the AHP alternative scales are listed in Appendix V.

Table 7.8: AHP weights of input and output variables of respondents (1-9 scale)

	Number of Employees	Number of Runways	Size of Terminal	Number of Passengers	Amount of Freight and Mails	Aircraft Movements
Respondent	*WI1*	*WI2*	*WI3*	*WO1*	*WO2*	*WO3*
1	0.0909	0.4545	0.4545	0.4545	0.4545	0.0909
2	0.0667	0.4667	0.4667	0.5591	0.3522	0.0887
3	0.0667	0.4667	0.4667	0.4667	0.4667	0.0667
4	0.0574	0.3643	0.5783	0.4444	0.4444	0.1111
5	0.0608	0.5861	0.3531	0.4545	0.4545	0.0909
6	0.0811	0.3420	0.5769	0.4286	0.4286	0.1429
7	0.0887	0.5591	0.3522	0.6370	0.2583	0.1047
8	0.0667	0.4667	0.4667	0.4579	0.4161	0.1260
9	0.0811	0.3420	0.5769	0.5469	0.3445	0.1085
10	0.0887	0.3522	0.5591	0.6955	0.2290	0.0754
11	0.6337	0.1744	0.1919	0.2081	0.1311	0.6608
12	0.1564	0.7450	0.0986	0.6608	0.2081	0.1311
13	0.1085	0.5469	0.3445	0.6370	0.2583	0.1047
14	0.0633	0.7429	0.1939	0.4434	0.1692	0.3874
15	0.1429	0.4286	0.4286	0.6608	0.2081	0.1311
Average	***0.1236***	***0.4692***	***0.4072***	***0.5170***	***0.3216***	***0.1614***
16	0.2599	0.4126	0.3275	0.2402	0.5499	0.2098
17	0.0751	0.3575	0.5675	0.4444	0.4444	0.1111
18	0.0754	0.2290	0.6955	0.6586	0.2628	0.0786
19	0.0836	0.4443	0.4721	0.4545	0.4545	0.0909
20	0.0810	0.1884	0.7306	0.6267	0.0936	0.2797
21	0.0650	0.5736	0.3614	0.4161	0.4579	0.1260
22	0.2098	0.5499	0.2402	0.4286	0.1429	0.4286
Average	***0.1214***	***0.3936***	***0.4850***	***0.4670***	***0.3437***	***0.1892***
Average in total	***0.1229***	***0.4452***	***0.4320***	***0.5011***	***0.3286***	***0.1703***

Table 7.9: Upper and lower bounds of variables weight ratios (scale 1-9)

Input weight ratio	Upper	Lower	Output Weight Ratio	Upper	Lower
WI1/WI2	3.6343	0.0851	*WO1/WO2*	6.6974	0.4368
WI1/WI3	3.3019	0.0992	*WO1/WO3*	9.2220	0.3150
WI2/WI3	7.5596	0.2578	*WO3/WO4*	7.0000	0.1984

7.3.2 RELATIVE EFFICIENCY ANALYSIS

The results of the DEA-BCC model, the AHP/DEA model, and the proposed AHP/DEA-AR are summarised in Table 7.10. It can be seen there are eight evaluation items for airport efficiency. The first column presents the efficiency scores, which are calculated using the original DEA-BCC model. The second column shows the efficiency scores, which are calculated using the AHP/DEA model. The weights for each variable are considered using a 1-9 scale. The third column shows the efficiency scores calculated using the DEA-AR model, and the weights of each variable are considered using a 1-9 scale. Columns four to eight reveal the efficiency scores, which are computed by the weights of each variable is considered in alternative scales.

An examination of VS II reveals that the number of efficient airports vary when using different analysis models, even in the case of the AHP/DEA-AR model, and by means of different AHP scales, the number of efficient airports vary as well (see Table 8.10).

(1) There are less efficient airports than inefficient airports (by means of the AHP/DEA-AR model).

(2) The result shows that in the proposed AHP/DEA-AR model, different scales can produce different numbers of efficient airports.

(3) The Standard Deviation (S.D.) of the efficiency score for the whole sample in the DEA-BCC model is 0.1698, and in the AHP/DEA model is 0.1947. However, the S.D. is from 0.2137, which is calculated by scale 2^{1-9} to 0.2471 that is calculated from scale Ø mapping in the proposed AHP/DEA-AR model. Therefore, these relative efficiency scores and S.D. indicate that the proposed AHP/DEA-AR model possesses better discriminatory power than either the DEA-BCC model or the AHP/DEA model.

(4) The results from the proposed model show that the mean of the efficiency scores for the whole sample in the 1-9 scale is 0.7206 (see Table 7.10), whereas the average efficiency scores for European airports is 0.7735, and for Asia-Pacific airports is 0.6677. In general, the efficiency of European airports is better than that of the Asia-Pacific region. Furthermore, it is worth noting that some Asian airports are performing well; for example, Hong Kong and Shenzhen are performing better than many European airports. However, Singapore Airport only achieved an efficiency score of 0.2852 among these 24 airports.

(5) Among those efficiency scores which were calculated using the AHP/DEA-AR model, the value of standard deviation shows that a ø mapping scale can provide more discriminatory power (S.D. is 0.2471).

(6) Table 7.11 reveals that when applying the AHP/DEA-AR model, the results show that privately operated airports can get higher efficiency than those that are publicly operated by conducting six different scales. When using the BCC model, public airports can achieve better efficiency, and when using the AHP/DEA model, private airports can achieve higher efficiency as compared to those that are public.

(7) Another benefit of using the AHP/DEA-AR model is to avoid extreme weight distribution. The weight distribution of variables for the DEA model is shown in Table 7.12. In regard to the discriminatory power and the distribution of variable weights, the proposed AHP/DEA-AR model makes the DEA and AHP/DEA results more accurate and also more able to reflect the actual decision-making situation for airport performance evaluation.

Table 7.10: Efficiency scores obtained using the AHP/DEA-AR model: VS II

DMU	DEA BCC Model	AHP/DEA model	**DEA-AR Model**					
			1	2	3	4	5	6
		1-9	1-9	e^{1-9}	2^{1-9}	9/9-9/1	10/10-18/2	Ø mapping
European								
Amsterdam (AMS)	0.9010	0.8460	0.7854	0.7858	0.7900	0.6909	0.7162	0.6849
Barcelona (BCN)	1	1	0.9325	0.9450	1	0.6900	0.7460	0.6752
Frankfurt (FRA)	0.9996	0.9115	0.9362	0.9365	0.9367	0.7513	0.7813	0.7443
Istanbul (IST)	0.7046	0.6776	0.6183	0.6175	0.6279	0.6048	0.6066	0.6043
London (LGW)	1	1	0.6429	0.6564	0.7221	0.4589	0.4999	0.4480
London (LHR)	1	1	1	1	1	1	1	1
Madrid (MAD)	1	1	0.8588	0.8694	0.9752	0.6093	0.6604	0.5964
Munich (MUC)	0.9030	0.5153	0.5566	0.5646	0.6572	0.3633	0.4047	0.3526
Paris (CDG)	1	1	1	1	1	0.9523	0.9778	0.9459
Paris (ORY)	**0.4810**	**0.4405**	0.3399	0.3450	0.3936	0.2306	0.2530	0.2249
Rome (FCO)	0.7629	0.6711	0.6115	0.6206	0.7033	0.4080	0.4508	0.3971
Zurich (ZRH)	1	1	1	1	1	1	1	1
Mean	0.8960	0.8385	0.7735	0.7784	0.8172	0.6466	0.6747	0.6395
Asia								
Bangkok (BKK)	0.8229	0.8212	0.6090	0.6147	0.6422	0.5699	0.5847	0.5662
Beijing (PEK)	1	1	0.7416	0.7463	0.7661	0.5421	0.5746	0.5344
Guangzhou (CAN)	0.7039	0.7355	0.6089	0.6099	0.6246	0.5782	0.5841	0.5768
Hong Kong (HKG)	1	1	1	1	1	1	1	1
Incheon (ICN)	0.9061	0.9061	0.8529	0.8534	0.8561	0.8483	0.8494	0.8474
Kuala Lumpur (KUL)	0.6493	0.6137	0.3902	0.3914	0.3990	0.3643	0.3735	0.3620
Osaka (KIX)	1	1	0.5872	0.5866	0.5963	0.5765	0.5780	0.5763
Tokyo (HRT)	1	1	0.6317	0.6326	0.6370	0.6234	0.6248	0.6231
Shanghai (PVG)	0.8065	0.7656	0.8026	0.8034	0.8047	0.7789	0.7825	0.7781
Singapore (SIN)	**0.4579**	**0.4294**	**0.2852**	**0.2884**	**0.3081**	**0.1891**	**0.2047**	**0.1854**
Shenzhen (SZX)	1	1	1	1	1	1	1	1
Sydney (SYD)	1	1	0.5028	0.5060	0.5549	0.4103	0.4295	0.4055
Mean	0.8622	0.8560	0.6677	0.6694	0.6824	0.6234	0.6321	0.6213
Mean of all samples	0.8791	0.8472	0.7206	0.7239	0.7498	0.6350	0.6534	0.6304
S.D.	0.1698	0.1947	0.2213	0.2206	0.2137	0.2452	0.2387	0.2471

Table 7.11: Airport efficiency with different ownership: VS II

DMU	Ownership category*	BCC	AHP/DEA model	AHP/DEA-AR					
				1-9	e^{1-9}	2^{1-9}	9/9-9/1	10/10-18/2	Ø mapping
Amsterdam (AMS)	(A)	0.901	0.846	0.7854	0.7858	0.79	0.6909	0.7162	0.6849
Istanbul (IST)	(A)	0.7046	0.6776	0.6183	0.6175	0.6279	0.6048	0.6066	0.6043
London (LGW)	(A)	1	1	0.6429	0.6564	0.7221	0.4589	0.4999	0.448
London (LHR)	(A)	1	1	1	1	1	1	1	1
Paris (CDG)	(A)	1	1	1	1	1	0.9523	0.9778	0.9459
Paris (ORY)	**(A)**	**0.481**	**0.4405**	**0.3399**	**0.345**	**0.3936**	**0.2306**	**0.253**	**0.2249**
Rome (FCO)	(A)	0.7629	0.6711	0.6115	0.6206	0.7033	0.408	0.4508	0.3971
Zurich (ZRH)	(A)	1	1	1	1	1	1	1	1
Sydney (SYD)	(A)	1	1	0.5028	0.506	0.5549	0.4103	0.4295	0.4055
Mean		0.8722	0.8484	0.7223	0.7257	0.7546	0.6395	0.6593	0.6345
S.D		0.1856	0.2067	0.2396	0.2372	0.2156	0.2889	0.2798	0.2913
Barcelona (BCN)	(B)	1	1	0.9325	0.945	1	0.69	0.746	0.6752
Frankfurt (FRA)	(B)	0.9996	0.9115	0.9362	0.9365	0.9367	0.7513	0.7813	0.7443
Madrid (MAD)	(B)	1	1	0.8588	0.8694	0.9752	0.6093	0.6604	0.5964
Munich (MUC)	(B)	0.903	0.5153	0.5566	0.5646	0.6572	0.3633	0.4047	0.3526
Bangkok (BKK)	(B)	0.8229	0.8212	0.609	0.6147	0.6422	0.5699	0.5847	0.5662
Beijing (PEK)	(B)	1	1	0.7416	0.7463	0.7661	0.5421	0.5746	0.5344
Guangzhou (CAN)	(B)	0.7039	0.7355	0.6089	0.6099	0.6246	0.5782	0.5841	0.5768
Hong Kong (HKG)	(B)	1	1	1	1	1	1	1	1
Incheon (ICN)	(B)	0.9061	0.9061	0.8529	0.8534	0.8561	0.8483	0.8494	0.8474
Kuala Lumpur (KUL)	(B)	0.6493	0.6137	0.3902	0.3914	0.399	0.3643	0.3735	0.362
Osaka (KIX)	(B)	1	1	0.5872	0.5866	0.5963	0.5765	0.578	0.5763
Tokyo (HRT)	(B)	1	1	0.6317	0.6326	0.637	0.6234	0.6248	0.6231
Shanghai (PVG)	(B)	0.8065	0.7656	0.8026	0.8034	0.8047	0.7789	0.7825	0.7781
Singapore (SIN)	**(B)**	**0.4579**	**0.4294**	**0.2852**	**0.2884**	**0.3081**	**0.1891**	**0.2047**	**0.1854**
Shenzhen (SZX)	(B)	1	1	1	1	1	1	1	1
Mean		0.8833	0.8466	0.7196	0.7228	0.7469	0.6323	0.6499	0.6279
S.D.		0.1663	0.1946	0.2184	0.2186	0.2201	0.2260	0.2210	0.2275

*(A) represents privately operated airports; (B) represents publicly operated airports.

Table 7.12: The weight distribution of variables in the AHP/DEA-AR model: VS II

DEA-BCC model			AHP/DEA model			AHP/DEA-AR model		
Wo1	Wo2	Wo3	Wo1	Wo2	Wo3	Wo1	Wo2	Wo3
0.3068	0	0	0	0.0120	0.0685	0.02777	0.39908	0.57315
0.4693	0	0.5307	0.0426	0	0	0.10495	0.05410	0.84095
0	0.2924	0	0	0.0143	0.0544	0.02626	0.45084	0.52289
0.1984	0	1.0215	0.0047	0.0501	0.0769	0.01208	0.74242	0.24550
0.4086	0.5914	0	0.0376	0	0	0.13713	0.06727	0.79560
0	0.8145	0.1855	0.0192	0	0	0.11991	0.78727	0.09282
0.3636	0.5807	0.0557	0.0253	0	0	0.11208	0.10832	0.77959
0	0.9949	0	0	0	0.0866	0.02187	0.10943	0.86870
0.1781	0.1227	0.6532	0	0.0216	0.0383	0.01374	0.58519	0.40107
0.4224	0.8466	0	0	0	0.1626	0.11891	0.09488	0.78621
0	0	0.8417	0	0	0.1079	0.11122	0.06481	0.82398
0.2336	0	0.7664	0.0468	0	0	0.13169	0.34507	0.52325
0.3052	0.7732	0	0.0274	0	0	0.13408	0.55133	0.31459
0.2155	0.6161	0	0.0230	0	0	0.09583	0.35000	0.55417
0.4992	0.4762	0.4977	0.0197	0.0524	0	0.02467	0.31868	0.65666
0.6591	0.3409	0	0.0270	0	0	0.01793	0.97001	0.01206
0.3183	0	0.2632	0	0.0426	0	0.00531	0.98247	0.01222
0.3543	0.8410	0	0.0016	0	0.1725	0.09656	0.34972	0.55372
0.4050	0	0.1256	0	0.1096	0.0282	0.00724	0.87623	0.11653
0.0161	0	0	0.0097	0.0371	0	0.06724	0.64609	0.28667
0	0	0	0	0.0260	0.0486	0.01124	0.65284	0.33592
0.3565	0.4350	0	0.0547	0.0073	0	0.10191	0.27662	0.62147
0	0	0.0691	0	0.1406	0.0369	0.01276	0.81644	0.17080
0	0	0	0.0392	0	0	0.02574	0.23163	0.74263

7.3.3 RELATIVE EFFICIENCY ANALYSIS IN DIFFERENT GROUPS

This section discusses the efficiency scores on the basis of VS II in two groups, an academic standpoint and a practical standpoint. Table 7.13 reveals that, from both standpoints, relatively efficient airports are pointed out when conducting an AHP/DEA-AR model based on alternative scales. A number of points emerge from Table 7.13, including:

(1) From both standpoints, in the relatively inefficient airports (which are calculated by different scales) it is easy to recognise the differences.

(2) The situation occurring in the AHP analysis is not found in Table 6.27, which is that when conducting alternative scales, the weights in scales 1 to 3 are close, and weights in scales 4-6 are also close.

(3) The efficient airports are slightly different from the academic viewpoint as compared to the practical viewpoint. Among inefficient airports, only Singapore and Paris (ORY) are found to have significantly lower efficiency.

(4) The efficiency scores and rankings of these two groups are similar to the results shown in Table 7.10.

Table: 7.13: Relative efficiency scores obtained using the AHP/DEA-AR model by groups: VS II

	Academia						Practice					
DMU	1-9	e^{1-9}	2^{1-9}	9/9-9/1	10/10-18/2	∅ mapping	1-9	e^{1-9}	2^{1-9}	9/9-9/1	10/10-18/2	∅ mapping
Amsterdam (AMS)	0.6169	0.6153	0.6124	0.6389	0.6318	0.6401	0.7854	0.7858	0.7900	0.6909	0.7162	0.6849
Barcelona (BCN)	0.4181	0.4120	0.4092	0.5059	0.4766	0.5111	0.9325	0.9343	0.5119	0.6900	0.7460	0.6752
Frankfurt (FRA)	0.6707	0.6693	0.6675	0.6931	0.6856	0.6942	0.9362	0.9365	0.9367	0.7513	0.7813	0.7443
Istanbul (IST)	0.5886	0.5871	0.5832	0.5971	0.5958	0.5977	0.6183	0.6027	0.6279	0.6048	0.6066	0.6043
London (LGW)	0.3068	0.3056	0.3148	0.3472	0.3322	0.3495	0.6429	0.6547	0.7221	0.4589	0.4999	0.4480
London (LHR)	1	1	1	1	1	1	1	1	1	1	1	1
Madrid (MAD)	0.4300	0.4266	0.4263	0.4832	0.4653	0.4863	0.8588	0.8496	0.9752	0.6093	0.6604	0.5964
Munich (MUC)	0.2295	0.2264	0.2209	0.2714	0.2578	0.2730	0.5566	0.5645	0.6572	0.3627	0.4045	0.3524
Paris (CDG)	0.8729	0.8710	0.8666	0.8979	0.8899	0.8989	1	1	1	0.9520	0.9777	0.9458
Paris (ORY)	**0.1587**	**0.1576**	**0.1585**	**0.1791**	**0.1721**	**0.1802**	**0.3399**	**0.3427**	**0.3936**	**0.2306**	**0.2530**	**0.2249**
Rome (FCO)	0.2562	0.2534	0.2527	0.3021	0.2868	0.3046	0.6115	0.6175	0.7033	0.4080	0.4508	0.3971
Zurich (ZRH)	1	1	1	1	1	1	1	1	1	1	1	1
Bangkok (BKK)	0.5336	0.5337	0.5367	0.5411	0.5381	0.5415	0.6090	0.6144	0.6422	0.5698	0.5847	0.5662
Beijing (PEK)	0.4618	0.4611	0.4636	0.4808	0.4739	0.4819	0.7416	0.7463	0.7661	0.5421	0.5746	0.5344
Guangzhou (CAN)	0.5485	0.5474	0.5449	0.5596	0.5562	0.5603	0.6089	0.6056	0.6246	0.5782	0.5841	0.5768
Hong Kong (HKG)	1	1	1	1	1	1	1	1	1	1	1	1
Incheon (ICN)	0.8482	0.8488	0.8489	0.8472	0.8476	0.8464	0.8524	0.8499	0.8557	0.8467	0.8481	0.8462
Kuala Lumpur (KUL)	0.3366	0.3361	0.3364	0.3441	0.3415	0.3446	0.3902	0.3886	0.3990	0.3643	0.3735	0.3620
Osaka (KIX)	0.5698	0.5693	0.5684	0.5724	0.5718	0.5727	0.5872	0.5743	0.5963	0.5765	0.5780	0.5763
Tokyo (HRT)	0.6211	0.6212	0.6220	0.6211	0.6210	0.6211	0.6317	0.6326	0.6370	0.6234	0.6248	0.6231
Shanghai (PVG)	0.7672	0.7673	0.7660	0.7716	0.7705	0.7718	0.8026	0.8034	0.8047	0.7789	0.7825	0.7781
Singapore (SIN)	**0.1504**	**0.1501**	**0.1510**	**0.1598**	**0.1564**	**0.1603**	**0.2852**	**0.2884**	**0.3081**	**0.1891**	**0.2047**	**0.1854**
Shenzhen (SZX)	1	1	1	1	1	1	1	1	1	1	1	1
Sydney (SYD)	0.3436	0.3418	0.3399	0.3644	0.3576	0.3657	0.5028	0.4979	0.5549	0.4103	0.4295	0.4055

7.3.4 HYPOTHESIS TESTING

This section describes, after conducting the AHP/DEA-AR model and having established the efficiency rankings of the sample airports, a hypothesis related to the rankings obtained needs to be tested. However, unlike Chapter 6, in this section, all of the results are used to test the hypothesis due to the varying outcomes for the efficiency scores.

Table 7.14 shows that all the significance levels (p) are not less than or equal to 0.05; therefore, the result is not significant. In other words, there is no statistically significant difference in airport efficiency between privately operated and publicly operated airports as calculated using the AHP/DEA-AR model with VS II.

Table 7.14: Mann-Whitney test of differences in efficiency: VS II

Reference	Scale	Mann-Whitney *U*-test	Mann-Whitney *Z*-test	Asymptotic Significance (two-tailed)
Privately managed airports vs. publicly managed airports	1-9	63	−0.270	0.815
	e^{1-9}	63	−0.270	0.815
	2^{1-9}	65.5	−0.120	0.907
	9/9-9/1	67	−0.030	1.000
	10/10-18/2	67	−0.030	1.000
	∅ mapping	66	−0.090	0.953

7.4 CROSS DISCUSSION AND ANALYSIS

Research Question 1 states that:

Does the result of airport efficiency vary as a result of conducting different evaluation methods?

The results of airport efficiency, which are evaluated using different methods and in different variables sets, are compared in this section.

Tables 7.15 and 7.16 show several evaluation items for airport efficiency in VS I and VS II. The first column presents the ownership category for each airport. The second column shows relative efficiency scores calculated using the original DEA-BCC model. The third column shows the relative efficiency scores calculated using the integrated AHP/DEA model (the weight of each variable is considered using a 1-9 scale).

Columns four to eight reveal the relative efficiency scores computed using the integrated AHP/DEA model (the weights of each variable are considered in alternative judgement scales). On the right hand side, columns one to six reveal the relative efficiency scores calculated using the AHP/DEA-AR model.

There is some evidence to support the supposition that the discriminatory power of the AHP/DEA-AR model is better than that of either the AHP/DEA model or the traditional DEA model. Firstly, when using AHP/DEA-AR model, the number of inefficient airports are increased not only in Table 7.15 but also in Table 7.16.

Secondly, when using the DEA-BCC and AHP/DEA models, the efficiency scores of publicly operated airports are higher than those of privately operated airports in both variable sets. However, by conducting the AHP/DEA-AR model, the results reverse in both variable sets. Consequently, Research Question 1 can be answered: the outcomes of airport efficiency evaluation vary as a result of combining evaluation techniques.

Thirdly, in both models, Paris (ORY) and Singapore (SIN) are the least two inefficient airports among the 24 sample airports. However, in Table 7.15 the scores do not help to display these differences. However, in Table 7.16, the scores can help to represent how far from others. Therefore, from this result, there is an indication of some evidence to support that when using DEA analysis, fewer numbers of variables can help to increase discriminatory power. However, this advantage cannot be addressed easily when only using the AHP/DEA-AR model.

Fourthly, a comparison of the AHP/DEA model and the AHP/DEA-AR model, as shown in the results in both tables, suggests that the latter model can help to raise the discriminatory power of the results. Finally, the efficiency scores in Table 7.15 and Table 7.16 explain that when using the AHP/DEA-AR model, a more robust result can be provided even when using different numbers of variables. To sum up the above discussion, the AHP/DEA-AR model can make the results more robust as compared to the other two models (the BCC model and the AHP/DEA model).

Table: 7.15: Relative efficiency scores obtained using the AHP/DEA model and the AHP/DEA-AR model: VS I

			AHP/DEA Model						AHP/DEA-AR Model					
DMU	Ownership category*	BCC	1-9	e^{1-9}	2^{1-9}	9/9-9/1	10/10-18/2	∅ mapping	1-9	e^{1-9}	2^{1-9}	9/9-9/1	10/10-18/2	∅ mapping
Amsterdam (AMS)	(A)	1	1	1	1	1	1	1	0.7589	0.7876	0.7933	0.6924	0.718	0.6862
Istanbul (IST)	(A)	1	1	1	1	1	1	1	0.7360	0.7715	0.8484	0.6356	0.6495	0.6296
London (LGW)	(A)	1	1	1	1	1	1	1	0.6167	0.6879	0.7341	0.4660	0.5092	0.4539
London (LHR)	(A)	1	1	1	1	1	1	1	1	1	1	1	1	1
Paris (CDG)	(A)	1	1	1	1	1	1	1	1	1	1	0.9530	0.9789	0.9467
Paris (ORY)	**(A)**	**0.6551**	**0.8205**	**0.8205**	**0.8205**	**0.8205**	**0.8205**	**0.8205**	**0.3541**	**0.4184**	**0.4734**	**0.2408**	**0.2676**	**0.2332**
Rome (FCO)	(A)	0.9983	1	1	1	1	1	1	0.6094	0.7208	0.7822	0.4224	0.4714	0.4088
Zurich (ZRH)	(A)	1	1	1	1	1	1	1	1	1	1	1	1	1
Sydney (SYD)	(A)	1	1	1	1	1	1	1	0.5793	0.6518	0.7774	0.4296	0.4572	0.4208
Mean		0.9615	0.9801	0.9801	0.9801	0.9801	0.9801	0.9801	0.7394	0.7820	0.8232	0.6489	0.6724	0.6421
S.D		0.1149	0.0598	0.0598	0.0598	0.0598	0.0598	0.0598	0.2264	0.1951	0.1693	0.2829	0.2712	0.2866
Barcelona (BCN)	(B)	1	1	1	1	1	1	1	0.9088	1	1	0.7027	0.7633	0.6856
Frankfurt (FRA)	(B)	1	0.9996	0.9996	0.9996	0.9996	0.9996	0.9996	0.8574	0.9412	0.9509	0.7538	0.7842	0.7462
Madrid (MAD)	(B)	1	1	1	1	1	1	1	0.8645	0.9761	1	0.6276	0.6871	0.6109
Munich (MUC)	(B)	1	1	1	1	1	1	1	0.4965	0.5901	0.6798	0.3666	0.4095	0.3555
Bangkok (BKK)	(B)	1	1	1	1	1	1	1	0.6436	0.6689	0.7590	0.5756	0.5923	0.5709
Beijing (PEK)	(B)	1	1	1	1	1	1	1	0.6579	0.746	0.7660	0.542	0.5746	0.5343
Guangzhou (CAN)	(B)	1	1	1	1	1	1	1	0.7168	0.762	0.8603	0.6048	0.6204	0.5986
Hong Kong (HKG)	(B)	1	1	1	1	1	1	1	1	1	1	1	1	1
Incheon (ICN)	(B)	0.9418	0.9944	0.9944	0.9944	0.9944	0.9944	0.9944	0.8531	0.8548	0.8555	0.8488	0.85	0.8477
Kuala Lumpur (KUL)	(B)	0.8975	0.8975	0.8975	0.8975	0.8975	0.8975	0.8975	0.4379	0.463	0.5418	0.3723	0.3842	0.3685
Osaka (KIX)	(B)	1	1	1	1	1	1	1	0.5923	0.6036	0.6138	0.5777	0.58	0.5766
Tokyo (HRT)	(B)	1	1	1	1	1	1	1	0.6343	0.6417	0.665	0.6256	0.6274	0.6247
Shanghai (PVG)	(B)	1	1	1	1	1	1	1	0.7907	0.8032	0.8046	0.7787	0.7822	0.7778
Singapore (SIN)	**(B)**	**0.8318**	**0.6672**	**0.6672**	**0.6672**	**0.6672**	**0.6672**	**0.6672**	**0.2471**	**0.2916**	**0.3135**	**0.1905**	**0.2063**	**0.1865**
Shenzhen (SZX)	(B)	1	1	1	1	1	1	1	1	1	1	1	1	1
Mean		0.9781	0.9706	0.9706	0.9706	0.9706	0.9706	0.9706	0.7134	0.7561	0.7873	0.6378	0.6574	0.6323
S.D.		0.0500	0.0880	0.0880	0.0880	0.0880	0.0880	0.0880	0.2139	0.2149	0.2001	0.2246	0.2195	0.2263

*(A) represents privately operated airports; (B) represents publicly operated airports.

Table: 7.16: Relative efficiency scores obtained using the AHP/DEA model and the AHP/DEA-AR model: VS II

			AHP/DEA Model						AHP/DEA-AR Model					
DMU	Ownership category*	BCC	1-9	e^{1-9}	2^{1-9}	9/9-9/1	10/10-18/2	Ø mapping	1-9	e^{1-9}	2^{1-9}	9/9-9/1	10/10-18/2	Ø mapping
Amsterdam (AMS)	(A)	0.9010	0.8460	0.8460	0.8460	0.8460	0.8460	0.8460	0.7854	0.7858	0.7900	0.6909	0.7162	0.6849
Istanbul (IST)	(A)	0.7046	0.6776	0.6773	0.6773	0.6773	0.6773	0.6773	0.6183	0.6175	0.6279	0.6048	0.6066	0.6043
London (LGW)	(A)	1	1	1	1	1	1	1	0.6429	0.6564	0.7221	0.4589	0.4999	0.448
London (LHR)	(A)	1	1	1	1	1	1	1	1	1	1	1	1	1
Paris (CDG)	(A)	1	1	1	1	1	1	1	1	1	1	0.9523	0.9778	0.9459
Paris (ORY)	(A)	**0.4810**	**0.4405**	**0.4405**	**0.4405**	**0.4405**	**0.4405**	**0.4405**	**0.3399**	**0.345**	**0.3936**	**0.2306**	**0.253**	**0.2249**
Rome (FCO)	(A)	0.7629	0.6711	0.6711	0.6711	0.6711	0.6711	0.6711	0.6115	0.6206	0.7033	0.408	0.4508	0.3971
Zurich (ZRH)	(A)	1	1	1	1	1	1	1	1	1	1	1	1	1
Sydney (SYD)	(A)	1	1	1	1	1	1	1	0.5028	0.506	0.5549	0.4103	0.4295	0.4055
Mean		0.8722	0.8484	0.8483	0.8483	0.8483	0.8483	0.8483	0.7223	0.7257	0.7546	0.6395	0.6593	0.6345
S.D		0.1856	0.2067	0.2068	0.2068	0.2068	0.2068	0.2068	0.2396	0.2372	0.2156	0.2889	0.2798	0.2913
Barcelona (BCN)	(B)	1	1	1	1	1	1	1	0.9325	0.945	1	0.69	0.746	0.6752
Frankfurt (FRA)	(B)	0.9996	0.9115	0.9115	0.9115	0.9115	0.9115	0.9115	0.9362	0.9365	0.9367	0.7513	0.7813	0.7443
Madrid (MAD)	(B)	1	1	1	1	1	1	1	0.8588	0.8694	0.9752	0.6093	0.6604	0.5964
Munich (MUC)	(B)	0.9031	0.5153	0.5153	0.5153	0.5153	0.5153	0.5153	0.5566	0.5646	0.6572	0.3633	0.4047	0.3526
Bangkok (BKK)	(B)	0.8229	0.8212	0.8212	0.8212	0.8212	0.8212	0.8212	0.609	0.6147	0.6422	0.5699	0.5847	0.5662
Beijing (PEK)	(B)	1	1	1	1	1	1	1	0.7416	0.7463	0.7661	0.5421	0.5746	0.5344
Guangzhou (CAN)	(B)	0.7039	0.7355	0.7355	0.7355	0.7355	0.7355	0.7355	0.6089	0.6099	0.6246	0.5782	0.5841	0.5768
Hong Kong (HKG)	(B)	1	1	1	1	1	1	1	1	1	1	1	1	1
Incheon (ICN)	(B)	0.9061	0.9061	0.9061	0.9061	0.9061	0.9061	0.9061	0.8529	0.8534	0.8561	0.8483	0.8494	0.8474
Kuala Lumpur (KUL)	(B)	0.6493	0.6137	0.6137	0.6137	0.6137	0.6137	0.6137	0.3902	0.3914	0.399	0.3643	0.3735	0.362
Osaka (KIX)	(B)	1	1	1	1	1	1	1	0.5872	0.5866	0.5963	0.5765	0.578	0.5763
Tokyo (HRT)	(B)	1	1	1	1	1	1	1	0.6317	0.6326	0.637	0.6234	0.6248	0.6231
Shanghai (PVG)	(B)	0.8065	0.7656	0.7656	0.7656	0.7656	0.7656	0.7656	0.8026	0.8034	0.8047	0.7789	0.7825	0.7781
Singapore (SIN)	**(B)**	**0.4579**	**0.4294**	**0.4294**	**0.4294**	**0.4294**	**0.4294**	**0.4294**	**0.2852**	**0.2884**	**0.3081**	**0.1891**	**0.2047**	**0.1854**
Shenzhen (SZX)	(B)	1	1	1	1	1	1	1	1	1	1	1	1	1
Mean		0.8833	0.8466	0.8466	0.8466	0.8466	0.8466	0.8466	0.7196	0.7228	0.7469	0.6323	0.6499	0.6279
S.D.		0.1663	0.1946	0.1946	0.1946	0.1946	0.1946	0.1946	0.2184	0.2186	0.2201	0.2260	0.2210	0.2275

7.5 ALTERNATIVE THOUGHTS ON AIRPORT EFFICIENCY ANALYSIS

7.5.1 STRAIGHTFORWARD AHP APPROACH

In this research, AHP is used to acquire the weights for each variable; another thought on how to apply AHP is offered in this section, which is to calculate efficiency score from AHP weights, and it is called the straightforward AHP approach. The first step of this approach is to standardise each variable and then to multiply the value with the weights of each variable. The final step is to add the value of all input and output variables individually and then to apply efficiency equation to show the final efficiency scores. The left side of Table 7.17 shows the raw data for VS I. The right side of Table 7.17 shows the value after standardisation. The amount in Table 7.18 reveals the result which is multiplied with the AHP weight and efficiency equation. The first column of this table is calculated from Table 7.17. The ratio column is calculated from the efficiency equation, which is the sum of actual outputs/ sum of actual inputs. Then, the final column is the efficiency computed using the straightforward AHP approach.

Take AMS airport as an example. Among these 24 sample airports, the maximum value in the number of employees is 17,996, which is selected from Frankfurt Airport (see Table 7.17). The value 14.33 is calculated from $(2{,}579/17{,}996)\times 100 = 14.33$. The result from Table 7.18 in the first column is $0.33 = 14.33\times 0.0228$.
The amount in ratio column =1.08
=$(0.33 + 4.18 + 8.64 + 4.05 + 4.34 + 33.23)/(15.75 + 6.16 + 4.55 + 32.51)$
The efficiency score in the final column is 0.6273= $(1.08/1.72)$.
The results for other columns all follow this calculation procedure.

Table 7.19 shows the efficiency score comparison calculated by means of different approaches. It reveals there to be eight scores for airport efficiency. The first column presents the efficiency scores, which are calculated using the basic DEA-CCR BCC model. The third column shows the efficiency scores calculated using the AHP/DEA-AR model. The forth column shows the efficiency scores calculated using the straightforward AHP approach. Columns five to eight reveal the efficiency scores, which are computed by the weights of each variable considered in VS II.

Table: 7.17: Progress on AHP approach: VSI (1)

	Input						Output				Input						Output			
	1	2	3	4	5	6	1	2	3	4	1	2	3	4	5	6	1	2	3	4
Max	17996	264	6	1382000	4090	1851.29	67056	3400000	559812	2891.66										
Amsterdam (AMS)	2579	94	6	591885	3244	985.64	47430	1567712	446693	1602.42	14.33	35.61	100	42.83	79.32	53.24	70.73	46.11	79.79	55.42
Barcelona (BCN)	569	101	3	155200	2850	290.36	30208	104239	321491	324.03	3.16	38.26	50.00	11.23	69.68	15.68	45.05	3.07	57.43	11.21
Frankfurt (FRA)	17996	174	3	800000	4000	1851.29	53467	2111116	485783	2104.52	100	65.91	50.00	57.89	97.80	100.00	79.73	62.09	86.78	72.78
Istanbul (IST)	1750	32	3	318500	2767	172.04	28533	766221	254531	283.98	9.72	12.12	50.00	23.05	67.65	9.29	42.55	22.54	45.47	9.82
London (LGW)	2186	107	1	202519	3316	584.43	34214	112366	263653	854.14	12.15	40.53	16.67	14.65	81.08	31.57	51.02	3.30	47.10	29.54
London (LHR)	5516	264	2	364800	3780	1820.23	67056	1486262	478693	2891.66	30.65	100	33.33	26.40	92.42	98.32	100.00	43.71	85.51	100
Madrid (MAD)	797	76	4	300000	3863	580.71	50846	328985	469740	647.92	4.43	28.79	66.67	21.71	94.45	31.37	75.83	9.68	83.91	22.41
Munich (MUC)	7400	200	2	458000	4000	1063.23	34552	274464	432296	1368.4	41.12	75.76	33.33	33.14	97.80	57.43	51.53	8.07	77.22	47.32
Paris (CDG)	3858	124	4	542595	3454	1084.6	60875	2040000	559812	1768.92	21.44	46.97	66.67	39.26	84.45	58.59	90.78	60.00	100	61.17
Paris (ORY)	3304	102	3	371500	3123	497.65	26210	140000	230167	732.32	18.36	38.64	50.00	26.88	76.36	26.88	39.09	4.12	41.12	25.33
Rome (FCO)	3278	86	4	285000	3677	477.66	35227	137424	346654	948.93	18.22	32.58	66.67	20.62	89.90	25.80	52.53	4.04	61.92	32.82
Zurich (ZRH)	1254	67	3	138614	3167	401.63	22099	387671	274991	789.76	6.97	25.38	50.00	10.03	77.43	21.69	32.96	11.40	49.12	27.31
Bangkok (BKK)	3245	120	2	563000	3850	432.04	46932	1291931	311435	733.69	18.03	45.45	33.33	40.74	94.13	23.34	69.99	38.00	55.63	25.37
Beijing (PEK)	1965	120	3	1382000	3600	517.26	55938	1367710	429646	561.6	10.92	45.45	50.00	100	88.02	27.94	83.42	40.23	76.75	19.42
Guangzhou (CAN)	3482	74	2	320000	3700	235.65	33435	685868	280392	378.69	19.35	28.03	33.33	23.15	90.46	12.73	49.86	20.17	50.09	13.10
Hong Kong (HKG)	1131	106	2	710000	3800	425.23	47700	3400000	296000	1120.93	6.28	40.15	33.33	51.37	92.91	22.97	71.13	100.00	52.87	38.76
Incheon (ICN)	933	90	3	600000	3833	396.64	29973	2423717	211102	973.92	5.18	34.09	50.00	43.42	93.72	21.43	44.70	71.29	37.71	33.68
Kuala Lumpur (KUL)	1578	106	2	479404	4090	256.8	27529	667495	209681	292.24	8.77	40.15	33.33	34.69	100.00	13.87	41.05	19.63	37.46	10.11
Osaka (KIX)	388	52	2	330000	3750	458.45	16014	846522	133502	959.15	2.16	19.70	33.33	23.88	91.69	24.76	23.88	24.90	23.85	33.17
Tokyo (HRT)	720	87	2	789700	3250	1109.51	32654	2100448	193321	1830.69	4.00	32.95	33.33	57.14	79.46	59.93	48.70	61.78	34.53	63.31
Shanghai (PVG)	6440	98	3	824000	3733	212.15	28236	2603027	265735	482.15	35.79	37.12	50.00	59.62	91.27	11.46	42.11	76.56	47.47	16.67
Singapore (SIN)	1396	102	3	1043020	3583	402.63	22877	415726	185304	921.99	7.76	38.64	50.00	75.47	87.60	21.75	34.12	12.23	33.10	31.88
Shenzhen (SZX)	3998	55	1	152000	3400	95.52	21401	598036	187942	217.22	22.22	20.83	16.67	11.00	83.13	5.16	31.92	17.59	33.57	7.51
Sydney (SYD)	306	65	3	387487	2978	136.47	32900	470000	298964	773.69	1.70	24.62	50.00	28.04	72.81	7.37	49.06	13.82	53.40	26.76

Table 7.18: Progress on AHP approach: VSI (2)

	Input						Output				Ratio	Final
	1	2	3	4	5	6	1	2	3	4		
weight	0.0228	0.1173	0.0864	0.0946	0.0547	0.6241	0.2227	0.1335	0.0570	0.5867		1.72
Amsterdam (AMS)	0.33	4.18	8.64	4.05	4.34	33.23	15.75	6.16	4.55	32.51	1.08	0.6273
Barcelona (BCN)	0.07	4.49	4.32	1.06	3.81	9.79	10.03	0.41	3.27	6.57	0.86	0.5021
Frankfurt (FRA)	2.28	7.73	4.32	5.48	5.35	62.41	17.76	8.29	4.95	42.70	0.84	0.4902
Istanbul (IST)	0.22	1.42	4.32	2.18	3.70	5.80	9.48	3.01	2.59	5.76	1.18	0.6880
London (LGW)	0.28	4.75	1.44	1.39	4.43	19.70	11.36	0.44	2.68	17.33	0.99	0.5794
London (LHR)	0.70	11.73	2.88	2.50	5.06	61.36	22.27	5.84	4.87	58.67	1.09	0.6339
Madrid (MAD)	0.10	3.38	5.76	2.05	5.17	19.58	16.89	1.29	4.78	13.15	1.00	0.5837
Munich (MUC)	0.94	8.89	2.88	3.14	5.35	35.84	11.48	1.08	4.40	27.76	0.78	0.4568
Paris (CDG)	0.49	5.51	5.76	3.71	4.62	36.56	20.22	8.01	5.70	35.89	1.23	0.7179
Paris (ORY)	0.42	4.53	4.32	2.54	4.18	16.78	8.70	0.55	2.34	14.86	0.81	0.4704
Rome (FCO)	0.42	3.82	5.76	1.95	4.92	16.10	11.70	0.54	3.53	19.25	1.06	0.6188
Zurich (ZRH)	0.16	2.98	4.32	0.95	4.24	13.54	7.34	1.52	2.80	16.02	1.06	0.6161
Bangkok (BKK)	0.41	5.33	2.88	3.85	5.15	14.56	15.59	5.07	3.17	14.89	1.20	0.7007
Beijing (PEK)	0.25	5.33	4.32	9.46	4.81	17.44	18.58	5.37	4.37	11.39	0.95	0.5560
Guangzhou (CAN)	0.44	3.29	2.88	2.19	4.95	7.94	11.10	2.69	2.85	7.68	1.12	0.6535
Hong Kong (HKG)	0.14	4.71	2.88	4.86	5.08	14.34	15.84	13.35	3.01	22.74	1.72	1
Incheon (ICN)	0.12	4.00	4.32	4.11	5.13	13.37	9.95	9.52	2.15	19.76	1.33	0.7766
Kuala Lumpur (KUL)	0.20	4.71	2.88	3.28	5.47	8.66	9.14	2.62	2.13	5.93	0.79	0.4584
Osaka (KIX)	0.05	2.31	2.88	2.26	5.02	15.46	5.32	3.32	1.36	19.46	1.05	0.6137
Tokyo (HRT)	0.09	3.87	2.88	5.41	4.35	37.40	10.84	8.25	1.97	37.14	1.08	0.6280
Shanghai (PVG)	0.82	4.35	4.32	5.64	4.99	7.15	9.38	10.22	2.71	9.78	1.18	0.6853
Singapore (SIN)	0.18	4.53	4.32	7.14	4.79	13.57	7.60	1.63	1.89	18.71	0.86	0.5031
Shenzhen (SZX)	0.51	2.44	1.44	1.04	4.55	3.22	7.11	2.35	1.91	4.41	1.20	0.6964
Sydney (SYD)	0.04	2.89	4.32	2.65	3.98	4.60	10.93	1.85	3.04	15.70	1.71	0.9933

Table 7.19: Efficiency scores using different approaches

	VSI				VSII			
Airport	**CCR**	**BCC**	**DEA/ AHP-AR**	**AHP**	**CCR**	**BCC**	**DEA/ AHP-AR**	**AHP**
Amsterdam (AMS)	1	1	0.7589	0.6273	0.712	0.901	0.7854	0.3720
Barcelona (BCN)	1	1	0.9088	0.5021	1	1	0.9325	0.4564
Frankfurt (FRA)	0.9899	1	0.8574	0.4902	0.7384	0.9996	0.9362	0.4799
Istanbul (IST)	1	1	0.7360	0.6880	0.693	0.7046	0.6183	0.4104
London (LGW)	1	1	0.6167	0.5794	1	1	0.6429	0.8563
London (LHR)	1	1	1	0.6339	1	1	1	1
Madrid (MAD)	1	1	0.8645	0.5837	1	1	0.8588	0.5267
Munich (MUC)	1	1	0.4965	**0.4568**	0.8263	0.903	0.5566	0.4541
Paris (CDG)	1	1	1	0.7179	0.9725	1	1	0.6261
Paris (ORY)	**0.6500**	**0.6551**	**0.3541**	0.4704	**0.4305**	**0.481**	**0.3399**	**0.2910**
Rome (FCO)	0.9711	0.9948	0.6094	0.6188	0.6803	0.7629	0.6115	0.3535
Zurich (ZRH)	1	1	1	0.6161	1	1	1	0.3924
Bangkok (BKK)	1	1	0.6436	0.7007	0.7817	0.8229	0.6090	0.6145
Beijing (PEK)	1	1	0.6579	0.5560	0.9276	1	0.7416	0.3731
Guangzhou (CAN)	0.9983	1	0.7168	0.6535	0.7036	0.7039	0.6089	0.5556
Hong Kong (HKG)	1	1	1	1	1	1	1	0.7569
Incheon (ICN)	0.9391	0.9418	0.8531	0.7766	0.8642	0.9061	0.8529	0.4670
Kuala Lumpur (KUL)	0.789	0.8844	0.4379	0.4584	0.6447	0.6493	0.3902	0.4016
Osaka (KIX)	1	1	0.5923	0.6137	0.8151	1	0.5872	0.3545
Tokyo (HRT)	1	1	0.6343	0.6280	0.9956	1	0.6317	0.4654
Shanghai (PVG)	1	1	0.7907	0.6853	0.6671	0.8065	0.8026	0.3863
Singapore (SIN)	0.7878	0.8318	**0.2471**	**0.5031**	**0.4423**	**0.4579**	**0.2852**	**0.1760**
Shenzhen (SZX)	1	1	1	0.6964	0.9609	1	1	0.7059
Sydney (SYD)	1	1	0.5793	0.9933	1	1	0.5028	0.4117
S.D.	0.0896	0.0791	0.2141	0.1417	0.1782	0.1698	0.2213	0.1863

An examination of the straightforward AHP approach with the AHP/DEA-AR model reveals that the number of efficient airports is similar, even in the AHP/DEA-AR model. Some other findings are as follows:

(1) The results from the straightforward AHP approach have only one airport is efficient for each variable set. In VSI is Hong Kong airport and in VSII is London Heathrow. The results are similar to other models. However, the numbers of efficient airport are much less than other approaches.

(2) On the opposite, the most inefficient airport calculated using the AHP weight approach in VSI is Munich, and in VSII is Singapore. The result in VSI is very different from the others, but the result in VSII is the same.

(3) The result shows that the proposed straightforward AHP approach can produce different numbers of efficient airports.

(4) The Standard Deviation (S.D.) of efficiency score for the whole sample, in the AHP weight approach decreased from 0.2141 to 0.1417 in VSI and decreased from 0.2213 to 0.1863 in VSII whereas the S.D. is decreased as compared to the AHP/DEA-AR model. However, the S.D. in the AHP weight approach was still higher than that of the basic DEA BCC and CCR models. Therefore, these relative efficiency scores and the S.D. indicate that the proposed AHP weight approach possesses better discriminatory power than either the DEA-BCC model or the DEA-CCR model.

(5) Table 7.19 indicates that the straightforward AHP approach can also provide higher discriminatory power results. It will be a very interesting approach for future research.

7.5.2 REFERRAL CLUSTER APPROACH

In this section, another airport efficiency calculation approach is discussed. In the basic DEA model, the outcome from the clustering analysis referral (details presented in Section 7.1.3) can help determine the relatively efficient airports, which are then used as the references and frequencies that improve the efficiencies of relatively inefficient enterprises (Zhu, 2009). The more an airport is referred, the more relatively efficient the airport is in the DMU group. Therefore, this approach can also provide some outputs which can generate efficiency scores. In addition, the clustering analysis referral can also be conducted when applying the AHP/DEA-AR model. Therefore, in this section, the results from these two models are discussed. Table 7.20 shows the clustering analysis referrals and efficiency from the basic DEA-BCC model and the AHP/DEA-AR model in two variable sets.

In Table 7.20, the first column presents the efficiency scores, which are calculated using the basic DEA-BCC model. The second column shows the referral frequency. The third column shows the rank reference, which is calculated from the referral frequency. For Sydney Airport, the referral frequency is the highest (5 in this model); subsequently we can give it the amount 24. London Heathrow Airport is the second highest among these 24 airports, hence we can assign 23 to it. Other airports can be followed in this order. Columns four to six show the results calculated using the

AHP/DEA-AR model. The right side of the table shows the results that are considered in VS II. In this table, relatively efficient airports can get higher scores. Therefore, in VSI, when calculating the efficiency scores using the BCC model, Sydney Airport is the most efficient airport, followed by London Heathrow. By means of the AHP/DEA-AR model, Paris (CDG) and Hong Kong are the most efficient airports. If comparison is made with Table 7.19, the results are similar. The comparison in VSII also shows a similar situation.

Table 7.20: The clustering analysis referrals and efficiency scores

	VSI						VSII					
	BCC			AHP/DEA-AR			BCC			AHP/DEA-AR		
DMU	Efficiency score	Referral Frequency	Rank reference	Efficiency score	Referral Frequency	Rank reference	Efficiency score	Referral Frequency	Rank reference	Efficiency score	Referral Frequency	Rank reference
Amsterdam (AMS)	1	1	15.5	0.7589	0	14	0.9010	0	9	0.7854	0	14
Barcelona (BCN)	1	1	15.5	0.9088	0	19	1	3	19.5	0.9325	0	18
Frankfurt (FRA)	1	0	9.5	0.8574	0	17	0.9996	0	12	0.9362	0	19
Istanbul (IST)	1	2	20	0.7360	0	13	0.7046	0	5	0.6183	0	10
London (LGW)	1	0	9.5	0.6167	0	8	1	3	19.5	0.6429	0	12
London (LHR)	1	3	23	1	10	21.5	1	6	22	1	13	24
Madrid (MAD)	1	1	15.5	0.8645	0	18	1	7	23	0.8588	0	17
Munich (MUC)	1	0	9.5	0.4965	0	4	0.9030	0	10	0.5566	0	5
Paris (CDG)	1	2	20	1	12	23.5	1	5	21	1	10	23
Paris (ORY)	0.6551	0	1	0.3541	0	2	0.4810	0	2	0.3399	0	3
Rome (FCO)	0.9948	0	5	0.6094	0	7	0.7629	0	6	0.6115	0	9
Zurich (ZRH)	1	2	20	1	10	21.5	1	1	17.5	1	8	21.5
Bangkok (BKK)	0.9937	0	9.5	0.6436	0	10	0.8229	0	8	0.6090	0	8
Beijing (PEK)	1	0	9.5	0.6579	0	11	1	2	18	0.7416	0	13
Guangzhou (CAN)	1	0	9.5	0.7168	0	12	0.7039	0	4	0.6089	0	7
Hong Kong (HKG)	1	2	20	1	12	23.5	1	9	24	1	8	21.5
Incheon (ICN)	0.9418	0	4	0.8531	0	16	0.9061	0	11	0.8529	0	16
Kuala Lumpur (KUL)	0.8845	0	3	0.4379	0	3	0.6493	0	3	0.3902	0	4
Osaka (KIX)	1	2	20	0.5923	0	6	1	1	17.5	0.5872	0	6
Tokyo (HRT)	1	0	9.5	0.6343	0	9	1	0	14	0.6317	0	11
Shanghai (PVG)	1	0	9.5	0.7907	0	15	0.8065	0	7	0.8026	0	15
Singapore (SIN)	0.8318	0	2	0.2471	0	1	0.4579	0	1	0.2852	0	2
Shenzhen (SZX)	1	1	15.5	1	3	20	1	0	14	1	4	20
Sydney (SYD)	1	5	24	0.5793	0	5	1	0	14	0.5028	0	1

7.5.3 THE COMPARISON BETWEEN MODELS

In this research, including the previous sections, six different approaches are applied to evaluate airport efficiency with two variable sets (i.e. the basic DEA-CCR and BCC models, the integrated AHP/DEA model, the AHP/DEA-AR model, the straightforward AHP approach, and the referral cluster approach in the BCC and AHP/DEA-AR models). In this section, a correlation coefficient analysis is adopted to show which models or approaches can provide the most reliable results. Table 7.21 shows all of the efficiency scores acquired in this research. As mentioned in Section 6.12, in this research, only the BCC model is discussed in the following section because the assumption of the BCC model is closer to an actual situation. In addition, when conducting AHP/DEA-AR analysis, the clustering analysis referral can also be undertaken. Therefore, the efficiency scores for the referral cluster approach calculated using the AHP/DEA-AR model are also included. The outcome of correlation coefficient analysis is displayed in Table 7.22. The reason for applying a correlation coefficient analysis is to help the author choose proper analysis models, which means that if two approaches have higher relationships, only one of them can be replaced by another one. Table 7.22 reveals that there are few of the results higher than 0.8 that implies when adopting these two approaches can provide similar results. In this case, the author can only choose one of them to evaluate airport efficiency. In variable set I, one of approaches between the AHP/DEA-AR and the AHP/DEA-AR rank reference can be reserved. In variable set II, AHP/DEA can replace both DEA-BCC and BCC referral frequency. One of approaches between the AHP/DEA-AR and AHP/DEA-AR rank references can be reserved.

Table 7.21: The efficiency scores using different models and approaches (1)

VSI							VSII					
DMU	BBCI	BCC Rank reference I	AHP/DEAI	AHP/DEA-AR I	AHP/DEA-AR Rank reference/AR I	AHPI	BBCII	BCC Rank reference II	AHP/DEA II	AHP/DEA-AR II	AHP/DEA-AR Rank reference II	AHP II
Amsterdam	1	15.5	1	0.7589	14	0.6273	0.9010	9	0.8460	0.7854	14	0.3720
Barcelona	1	15.5	1	0.9088	19	0.5021	1	19.5	1	0.9325	18	0.4564
Frankfurt	1	9.5	1	0.8574	17	0.4902	0.9996	12	0.9115	0.9362	19	0.4799
Istanbul	1	20	1	0.7360	13	0.6880	0.7046	5	0.6776	0.6183	10	0.4104
London (LGW)	1	9.5	1	0.6167	8	0.5794	1	19.5	1	0.6429	12	0.8563
London (LHR)	1	23	0.8205	1	21.5	0.6339	1	22	1	1	24	1
Madrid	1	15.5	1	0.8645	18	0.5837	1	23	1	0.8588	17	0.5267
Munich	1	9.5	1	0.4965	4	0.4568	0.9030	10	0.5153	0.5566	5	0.4541
Paris (CDG)	1	20	1	1	23.5	0.7179	1	21	1	1	23	0.6261
Paris (ORY	0.6551	1	1	0.3541	2	0.4704	0.4810	2	0.4405	0.3399	3	0.2910
Rome	0.9948	5	1	0.6094	7	0.6188	0.7629	6	0.6711	0.6115	9	0.3535
Zurich	1	20	1	1	21.5	0.6161	1	17.5	1	1	21.5	0.3924
Bangkok	0.9937	9.5	1	0.6436	10	0.7007	0.8229	8	0.8212	0.6090	8	0.6145
Beijing	1	9.5	0.9996	0.6579	11	0.5560	1	18	1	0.7416	13	0.3731
Guangzhou	1	9.5	1	0.7168	12	0.6535	0.7039	4	0.7355	0.6089	7	0.5556
Hong Kong	1	20	1	1	23.5	1	1	24	1	1	21.5	0.7569
Incheon	0.9418	4	1	0.8531	16	0.7766	0.9061	11	0.9061	0.8529	16	0.4670
Kuala Lumpur	0.8845	3	1	0.4379	3	0.4584	0.6493	3	0.6137	0.3902	4	0.4016
Osaka	1	20	1	0.5923	6	0.6137	1	17.5	1	0.5872	6	0.3545
Tokyo	1	9.5	1	0.6343	9	0.6280	1	14	1	0.6317	11	0.4654
Shanghai	1	9.5	0.9944	0.7907	15	0.6853	0.8065	7	0.7656	0.8026	15	0.3863
Singapore	0.8318	2	0.8975	0.2471	1	0.5031	0.4579	1	0.4294	0.2852	2	0.1760
Shenzhen	1	15.5	1	1	20	0.6964	1	14	1	1	20	0.7059
Sydney	1	24	1	0.5793	5	0.9933	1	14	1	0.5028	1	0.4117

Table 7.22: The efficiency scores using different models and approaches (2)

	BCCI	BCC Rank reference I	AHP/DEA I	AHP/DEA -AR I	AHP/DEA -AR Rank reference I	AHPI	BCCII	BCC Referral Frequency II	AHP/DEA II	AHP/DEA -AR II	AHP/DEA -AR Rank reference II	AHP II
BCCI	1											
BCC Rank reference I	0.5890	1										
AHP/DEAI	0.1179	-0.1206	1									
AHP/DEA-AR	0.6005	0.6282	-0.0062	1								
AHP/DEA-AR Rank reference I	0.5053	0.5747	-0.0670	**0.9782**	1							
AHPI	0.3536	0.5359	0.1009	0.4014	0.3580	1						
BCCII	0.7581	0.6442	0.1352	0.6956	0.6021	0.3364	1					
BCC Referral Frequency II	0.5302	0.6629	-0.0700	0.6723	0.6494	0.3127	**0.8677**	1				
AHP/DEA II	0.6643	0.6554	0.0854	0.7318	0.6606	0.4476	**0.9093**	**0.8549**	1			
AHP/DEA-AR II	0.5871	0.5562	-0.0285	**0.9752**	**0.9643**	0.2986	0.7396	0.7159	0.7326	1		
AHP/DEA-AR Rank reference II	0.4565	0.4626	-0.1491	**0.9306**	**0.9554**	0.1941	0.6287	0.6847	0.6545	**0.9659**	1	
AHP II	0.4034	0.4159	-0.3230	0.5767	0.5442	0.3083	0.5108	0.5954	0.5250	0.5489	0.5736	1

7.5.4 ANOTHER HYPOTHESES TESTING METHOD

According to Hair and Black (2010), multiple regression is the use of two or more independent variables in the prediction of the dependent variable. The task for a researcher is to expand upon the simple regression model by adding independent variable(s) that have the greatest additional predictive power. In this section, we might expect the ownership of an airport and the location of an airport to result in higher efficiency scores. In this research, we hope to answer the question: Does airport ownership affect airport operational efficiency? In there, efficiency scores derived from conducting the AHP/DEA-AR model are applied as the dependent variable, and airport ownership is applied as the independent variable. Table 7.23 determines if there is overwhelming evidence at the $\boldsymbol{\alpha} = \mathbf{0.05}$ level of a linear relationship between operational efficiency and airport ownership. A t-test with n-2 degrees of freedom is used. The critical values are 2.06 and -2.06. The *t-test* static is -0.05, and since -0.05 >-2.06, we accept the null hypothesis that there is no significant relation between efficiency and airport ownership.

Table 7.23: The result of regression analysis (1)

Regression Statistics						
Multiple R	0.0111					
R Square	0.0001					
Adjusted R Square	-0.0475					
Standard Error	0.4984					
Observations	23.0000					
ANOVA						
	df	*SS*	*MS*	*F*	*Significance F*	
Regression	1	0.0006	0.0006	0.0026	0.9600	
Residual	21	5.2168	0.2484			
Total	22	5.2174				
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	0.3650	0.3533	1.0329	0.3134	-0.3698	1.0997
Privatised	-0.0239	0.4705	-0.0507	0.9600	-1.0023	0.9545

Furthermore, if adding another variable (location of airport), the question becomes: Do airport ownership and airport location affect airport operational efficiency? From Table 7.24, it can be seen that another method is used to test the hypothesis: the *p* value method. The *p* value is the probability of observing a test statistic more extreme than what we observed. In this research, the p values are 0.702 and 0.323, and both of them are large than 0.05. Therefore the null hypothesis is accepted. This means that both airport ownership and location have no relationship with airport operational efficiency.

Table 7.24: The result of regression analysis (2)

Regression Statistics						
Multiple R	0.2242					
R Square	0.0503					
Adjusted R Square	-0.0402					
Standard Error	0.2184					
Observations	24					
ANOVA						
	df	*SS*	*MS*	*F*	*Significance F*	
Regression	2	0.0530	0.0265	0.5556	0.5819	
Residual	21	1.0017	0.0477			
Total	23	1.0548				
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	0.7966	0.0995	8.0095	0.0000	0.5898	1.0034
Privatised	-0.0446	0.1154	-0.3867	0.7029	-0.2846	0.1953
Asian	-0.1135	0.1117	-1.0157	0.3213	-0.3458	0.1189

7.6 SUMMARY

The first section of this chapter described the concepts and analysis process of efficiency scores using the AHP/DEA-AR model. The second and third sections described the efficiency scores computed on VS I and VS II. The last section described the results and compared them with those of the DEA-BCC model and the integrated AHP/DEA model.

The Mann-Whitney test shows that the hypothesis that airports under private management are more efficient than those under public management was not significant in the case of both variable sets. The results reveal that the outcome of airport efficiency is influenced by combining different evaluation techniques. In addition, the AHP/DEA-AR model can also provide better discriminatory power for examiners to use when evaluating airport performance.

In addition, by using Saaty's 1-9 scale, it can be seen that the AHP/DEA-AR model provided a fair and useful technique by which to evaluate the performance of airports in terms of their relative efficiencies, not only on the basis of the quality of variables but also on the basis of the integration of diverse viewpoints. Moreover, when introducing alternative judgement scales to the AHP model, the results were found to be more robust as compared to the integrated AHP/DEA model, and these differences were very significant. Therefore, this kind of calculation method can provide realistic results when benchmarking airports. This means that relatively inefficient airports can be identified to policy makers and civil aviation authorities.

In the last section, alternative thoughts about airport efficiency evaluation approaches and hypothesis testing were presented. In this section, more possibilities for future research are suggested.

CHAPTER 8

RESEARCH CONCLUSIONS

This final chapter starts with a brief summary of the entire research and then focuses primarily on the researching findings that provide the answers to the research questions, followed by the theoretical and methodological contributions and the managerial implications of this study. Finally, the research concludes with some limitations and highlights for future research.

8.1 RESEARCH CONCLUSIONS

The aims of this research were to examine the relationships between airport efficiency and airport ownership or governance and to establish a reliable AEES. The research was conducted using a number of different analytical methods. To achieve these aims, it was necessary first to hypothesise this relationship and then to empirically examine the relationship, and these two main tasks were accomplished through the use of a pilot study intended to develop the AEES variables and an empirical study intended to evaluate the relative efficiency of the airports under consideration.

A structured literature review defined the research gaps in research on this topic and provided the inspiration for preliminary evaluation variables. In addition, a number of methodological findings were also addressed (see Chapter 2). The recent revolution in airport ownership and governance were described in order to help the author decide the target regions and sample airports (see Chapter 3). A theoretical basis for the development of the research design was then described and addressed (see Chapter 4). The analytical methods for this research were expanded from the common approach (the DEA method) to include an integrated AHP/DEA model, which has not yet been employed previously to evaluate airport efficiency. In addition, the recommendations of one of the experts who was interviewed were followed, and the AHP was subsequently adopted in this research. Alternative scales were also used when conducting the AHP method (see Chapter 4).

The AHP questionnaire survey was conducted in two fields (i.e. practice and academia). A general picture of survey participants and their responses to the questions were provided by the use of descriptive statistics (see Chapter 5). The airport efficiency computed using the basic DEA models and an integrated AHP/DEA model were then compared (see Chapter 6). A sensitivity analysis of the DEA model was also conducted. Subsequently, another efficiency evaluation method (i.e. an AHP/DEA-AR model) was used in this research, and the results were compared with the other evaluation methods. In addition, some other thoughts about efficiency evaluation and hypothesis testing approaches were also described (see Chapter 7).

8.2 RESEARCH FINDINGS

Revisiting the proposed Research Questions in Chapter 1, the following section presents a brief summary of the key findings in accordance with of the each individual research questions.

Research Question 1:
Does the result of airport efficiency vary as a result of conducting different evaluation methods?

One the aims of this research is to determine airport efficiency using several different evaluation techniques, (i.e. basic DEA models, which include the CCR and BCC models, the integrated AHP/DEA model and the AHP/DEA-AR model), to evaluate 24 sample airports. The results show very clearly that adopting different evaluation methods have an effect on the evaluation results in several ways, such as increases in both the number of inefficient airports and the discriminatory power of the results (addressed by mean and Standard Deviation of the efficiency scores). From Table 8.1, the evidence shows that conducting different evaluation methods does change the efficiency scores obviously.

Research Question 2:
Would an airport privatisation policy (airport ownership) influence the performance of an airport's operation?

The second Research Question examines if airports under private management are more efficient than those under public management (as proposed and empirically tested in Chapters 6 and 7). In this research, two variable sets (i.e. ten variables and six variables) and three evaluation techniques are used. In addition, six alternative scales are conducted by means of an AHP analysis. Table 8.1 shows a summary of efficiency scores in the different models and the results of the Mann-Whitney test.

A hypothesis was set that the efficiency of privately operated airports should be shown to be significantly different from those that are publicly operated. However, the results using DEA-BCC models, the integrated AHP/DEA model, and the AHP/DEA-AR model to evaluate airport efficiency, indicated no statistically significant difference in airport efficiency between privately operated and publicly operated airports, even with the application of two variable sets.

Although all of the results show that there to be no statistically significant difference, efficiency scores which were calculated using the AHP/DEAAR model still provided some evidence indicating that privately operated airports are more efficient than those that are operated publicly.

Table 8.1: Summary of efficiency scores and the Mann-Whitney test

		Method	DEA	AHP/DEA	AHP/DEA-AR
Average efficiency scores	Public	VSI	0.9780	0.9706	0.7134
		S.D.	0.0500	0.0880	0.2139
		VSII	0.8833	0.8466	0.7196
		S.D.	0.1663	0.1946	0.2184
	Private	VSI	0.9615	0.9801	0.7394
		S.D.	0.1149	0.0598	0.1951
		VSII	0.8612	0.8484	0.7223
		S.D.	0.1799	0.2067	0.2396
Mann-Whitney test	VSI	Z	−0.1260	−0.7980	−0.4490
		p	0.9000	0.5990	0.6530
	VSII	Z	−0.1270	−0.1910	−0.2700
		p	0.8990	0.8610	0.8150

Research Question 3:

Does the influence of alternative scales on the results of the AHP analysis cause a different weight for each variable?

The use of alternative comparison scales within AHP is discussed in Chapter 5. As described, a series of pair-wise comparisons and a unit scale are used in the AHP to play a fundamental role in quantifying a DM's preference judgements. To date, the Saaty 1-9 scale is the most used 9-unit scale in the AHP. Furthermore, although some authors (see Chapter 4) have tried to debate the appropriateness of a 1-9 scale, the AHP literature has not yet addressed which of the available alternative scales are most appropriate for the process of making pair-wise comparisons. The influence of alternative scales on the results of the AHP analysis is assessed in this research.

To overcome the deficiencies of the 1-9 scale, various judgement scales for a pair-wise comparison were proposed and evaluated. In this research, Saaty's 1-9 scale and other five alternative scales were used to calculate the weights of each variable (i.e. e^{1-9}, 2^{1-9} 9/9-9/1, 10/10-18/2, ø mapping). The results of the AHP analysis in Chapter 6 show that alternative scales cause a different weight for each variable; however, the difference was not shown to be significant (see Table 5.15). In addition, the outcome also revealed that scales 1-9, e^{1-9} and 2^{1-9} can produce similar weights and that scales 10/10-18/2 and ø mapping can result in similar weights. Moreover, applying these weights with DEA, the efficiency scores did not demonstrate obvious differences, but with the DEA-AR models, the differences among the efficiency scores can be easily recognised.

Research Question 4

Does the number of input and output variables affect the results of airport efficiency evaluation?

In order to answer this research question, two variables (ten variables and six variables) were undertaken in the DEA analysis in this research. An insufficient number of variables for a DEA model will tend to rate all DMUs as being 100% efficient because of an inadequate number of degrees of freedom. Hence, a proper variablesnumber is required for identifying a true performance frontier (Zhang and Bartels, 1998). A rule of thumb for maintaining an adequate number of degrees of freedom when using DEA is to obtain at least two variables for each input or output measure (Bowlin, 1987). In addition, Cooper et al. (2006) found that this also to be a part of DEA sensitivity analysis. The results from Chapter 6 and Chapter 7 show that the numbers of variables do affect the results related to airport efficiency. Furthermore, using fewer numbers of variables (in this research in VSII) or the use of the AHP/DEA-AR model can provide a higher discriminatory power for the AEES.

8.3 CONTRIBUTIONS AND IMPLICATIONS

The key highlights of the proposed research contributions and managerial implications are discussed in this section.

8.3.1 THEORETICAL CONTRIBUTIONS

Firstly, to the best of author's knowledge, this research is the first effort to make a comparative assessment of the impact of airport ownership or governance on efficiency involving European and Asia-Pacific airports. There have been some previous studies that have not focused on a specific region, such as Oum et al. (2006), who focused on 109 airports around the world, or Lin and Hong (2006), who evaluated 20 major airports around the world. Although Oum et al. (2006) showed that airport ownership affects airport efficiency, Lin and Hong (2006) found that airport efficiency is not affected by airport ownership. This difference may be due to the time differences between these two studies: Oum et al.'s (2006) study covered a four year period between 2003 and 2005 while Lin and Hong (2006) only used data drawn from a one year period.

Secondly, this research has objectively established an Airport Efficiency Evaluation System (AEES). A two steps AHP analysis was conducted in this research (i.e. a pilot semi-structured interview and structured interview or questionnaire survey). Following this survey, 38 experts in total were selected from academia and practice for interviews (i.e. three experts in the pilot interview and 35 experts in the questionnaire survey).

Thirdly, this research is the first research to conduct a structured literature review on the development of benchmarking techniques in airport performance evaluation research. From this literature review, the measurement methodologies, the variables used, and the results associated with various airport activities have been realised. In addition, some attention has been given to the increased employment of mathematical modelling and advanced statistical analysis methods.

Finally, this research is also the first research to apply two different evaluation models (i.e. the AHP/DEA model and the AHP/DEA-AR model) to evaluate airport efficiency with an AEES.

8.3.2 METHODOLOGICAL CONTRIBUTIONS

This research has made an important contribution in terms of methodology. It is the first effort to adopt AHP alternative scales, an integrated AHP/DEA model, and an integrated AHP/DEA-AR model on airport performance. Although the AHP method has been widely employed in many other studies (which were mentioned in Chapter 5), it has not previously been used to assess airport efficiency. Therefore, the analysis process described and practiced in this study can provide guidance to air transport researchers who wish to use these techniques.

In particular, the analytical technique used in this research addressed various issues and included advanced techniques in AHP and DEA. Firstly, DEA was compared with other similar techniques, such as SFA and TFP (see Chapter 2). This comparison provided some useful information on the advantages and disadvantages of DEA over the other techniques and the situations where DEA needs to be used.

Secondly, in this study, alternative scales of AHP were conducted, which have been argued in AHP literature for a long time. This research selected five other scales to calculate the weights of variables, which were compared with Saaty’s 1-9 scale.

Thirdly, multiple groups of experts were interviewed in the AHP analysis. The multiple group analysis in this study covered most of the possible interviewees in airport efficiency. This means that the AEES can be established more reliably.

Fourthly, some other thoughts about efficiency evaluation implied from AHP weights and cluster analysis as well as hypothesis testing are introduced in this research. Although the whole process is still not very mature, it also provides some guidance for future research.

8.3.3 MANAGERIAL IMPLICATIONS AND PRACTICAL CONTRIBUTIONS

For practitioners, the identification of the variables affecting airport operations explored in this study may stimulate more carefully considered transport decision-making by providing a more accurate and precise framework for airport planning. The slack analysis can also provide guidance by which to set up targets to improve airport efficiency.

Secondly, the review of the devolution of airport governance and ownership in different countries can also help policy makers and practitioners gain some experience and feedback when deciding to change the ownership or governance of airports. In addition, the results of this research also can provide some evidence to persuade people to support airport privatisation policy.

Finally, an AEES was built in this research, and this system provided several variables based on finance, service, and airport capacity. By means of this system, airport managers or airport authorities can assess their airports easily or provide some guidelines that will enable them to establish their own variable set.

8.4 LIMITATIONS AND SUGGESTIONS FOR FURTHER RESEARCH

Any study encounters limitations, and this study is no exception. The limitations in this study can provide potential directions for further research.

Firstly, this study only successfully interviewed 22 experts in the area of air transport. Future research can try to expand the number of experts; in that case, the AEES or research results may have different results or concepts. In addition, the experts in this research only included two points of view (i.e. scholars and airport managers), whereas additional research could investigate the proposed variables from the civil aviation authority perspective concurrently. Therefore, a new viewpoint may aid in the accumulation of information and provide new insights into this topic. Secondly, other qualitative approaches (such as a focus group or Delphi studies) could be adapted to construct the weights of each variable. Thirdly, the application of the AEES could be taken into other geographical areas to cross-validate the findings of this research. As pointed out in Chapter 1, the Asia-Pacific region and Europe were selected as the location of interest for this study. Therefore, confidence in the applicability of the research model can be increased if the cross-validation and invariance of the model are verified in other geographical locations.

As mentioned in Chapter 5, only one year’s worth of panel data of the sample airports was applied in this research. Therefore, it is recommended that a study that gathers more panel data would be able to increase the confidence of the applicability of the research model. Finally, only major airports were selected in this research because of the problem of data availability. It is therefore recommended that future research apply this model to medium or small airports to increase the confidence in regard to the applicability of the research model.

∞ BIBLIOGRAPHY ∞

Aastrup, J. and Halldorsson, A. 2008. Epistemological role of case studies in logistics: A critical realist perspective, *International Journal of Physical Distribution & Logistics Management,* 38(10), pp. 746-763.

Abbott, M. and Wu S. 2002. Total Factor Productivity and efficiency of Australian airports. *The Australian Economic Review* 35(3), pp. 244-260.

Ablanedo-Rosas, J.H. and Gemoets, L.A. 2010. Measuring the efficiency of Mexican airports. *Journal of Air Transport Management* 16(6), pp. 343-345.

Adler, N. and Berechman, J. 2001. Measuring airport quality from the airlines' viewpoint: An application of data envelopment analysis. *Transport Policy* 8(3), pp. 171-181.

Aguarón, J., and Moreno-Jiménez, J.M. 2004. The geometric consistency index. Approximated thresholds. *European journal of operational research* 147(1), pp.137-145.

Airport Council International. 2011. *ACI Airport Economics Survey 2010*. Geneva: ACI.

Aigner, D.J., Lovell, C.A.K., and Schmidt, P. 1977. Formulation and estimation of stochastic frontier production function models. *Journal of Econometrics* 6(1), pp. 21-37.

Airbus. 2012. *Global market forecast.* Lavaur: Airbus.

Ali, I., Charnes, A., Cooper, W., Divine, D., Klopp, G.A., and Stutz, J. 1987. An application of data envelopment analysis to US Army recruitment districts. In: Schultz, R.L. ed. *Applications of management science.* New York: JAI press.

Ali, A., Seiford, L.M. 1993. The mathematical programming approach to efficiency analysis. In: Fried, H.O., Lovell, C.A.K., and Schmidt, S.S. ed. *The Measurement of Productive Efficiency: Techniques and Applications*. New York: Oxford University Press.

Allen, R., Athanassopoulos, A., Dyson, R.G., and Thanassoulis, E. 1997. Weights restrictions and value judgements in Data Envelopment Analysis: Evolution, development and future directions. *Annals of operations research* 73, pp. 13-34.

Anderson L., Walberg H.J., and Weinstein, T. 1998. Efficiency and effectiveness analysis of Chicago public elementary schools: 1989, 1991, 1993. *Educational Administration Quarterly* 34(4), pp. 484-504.

Arbel, A. 1989. Approximate articulation of preference and priority derivation. *European journal of operational research* 43(3), pp. 317-326.

Armitage, A. and Keeble-Allen, D. 2008. Undertaking a Structured Literature Review or Structuring a Literature Review: Tales from the Field. *The Electronic Journal of Business Research Methods* 6(2), pp. 103-114.

Ashford, N. and Moore, C. A. 1992. *Airport finance*. New York: Van Nostrand Reinhold.

Assaf, A. 2009. Accounting for size in efficiency comparisons of airports. *Journal of Air Transport Management* 15(5), pp. 256-258.

Assaf, A. 2010. The cost efficiency of Australian airports post privatization. *Tourism Management* 31(2), pp. 267-273.

Assaf, A. 2011. Bootstrapped Malmquist indices of Australian airports. *The Service Industries Journal* 31(5), pp. 829-846.

Assaf, A and Gillen, D. 2012. Measuring the joint impact of governance form and economic regulation on airport efficiency. *European journal of operational research* 220(1), pp. 187-198.

Assaf, A, Gillen, D., and Barros, C. 2012. Performance assessment of UK airports: Evidence from a Bayesian dynamic frontier model. *Transportation research part E* 48(3), pp. 603-615.

Avison, D.E. and Fitzgerald. G. 1995. *Information systems development: methodologies, techniques and tools*. London: McGraw-Hill.

Azadeh, A., Ghaderi, S.F. and Izadbakhsh, H. 2008. Integration of DEA and AHP with computer simulation for railway system improvement and optimization. *Applied Mathematic and computation* 195, pp. 775-785.

BAA. (2011). *BAA history*. [online]. London: BAA. Available at: http://www.baa.com/. [Accessed 25th January 2011].

BAA. (2012). *BAA history*. [online]. London: BAA. Available at: http://www.baa.com/. [Accessed 31st August 2012].

Banker, R.D., Charnes, A., and Cooper, W. 1984. Some models for estimating technical and scale inefficiencies in Data Envelopment Analysis. *Management science* 30(9), pp. 1078-1092.

Barros, C.P. 2008a. Airports in Argentina: Technical efficiency in the context of an economic crisis. *Journal of Air Transport Management* 14(6), pp.315-319.

Barros, C.P. 2008b. Technical efficiency of UK airports. *Journal of Air Transport Management* 14(4), pp. 175-178.

Barros, C.P. 2009. The measurement of efficiency of UK airports: Using a stochastic latent class frontier model. *Transport Reviews* 29(4), pp.479-498.

Barros. C. P. 2011. Cost efficiency of African airports using a finite mixture model. *Transport Policy* 18(6), pp. 807-813.

Barros, C.P. and Dieke, P.U.C. 2007. Performance evaluation of Italian airports: A data envelopment analysis. *Journal of Air Transport Management* 13(4), pp. 184-191.

Barros, C.P. and Dieke, P.U.C. 2008. Measuring the economic efficiency of airports: A Simar-Wilson methodology analysis. *Transportation Research Part E* 44(6), pp. 1039-1051.

Barros, C. P., Managi, S., and Yoshida, Y. 2010. Technical efficiency, regulation and heterogeneity in Japanese airports. *Pacific Economic Review* 15(5), pp. 685-696.

Barros, C.P. and Sampaio, A. 2004. Technical and allocative efficiency in airports. *International Journal of Transport* Economics 31(3), pp. 355-378.

Bazargan, M. and Vasigh, B. 2003. Size verus efficiency: a case study of US commercial airports. *Journal of Air Transport Management* 9(3), pp. 187-193.

Bech, M. and Kristensen, M.B. 2009. Differential response rates in postal and web-based survey among older respondents. *Survey research methods* 3(1), pp. 1-6.

Beesley, M. E. 1997. *Privatization, Regulation and Deregulations*, 2nd ed. London: Routledge.

Behzadian, M., Kazemzadeh, R.B., Albadvi, A., and Aghdasi, M. 2009. PROMETHEE: A comparative analysis literature review on methodologies and applications. *European Journal of Operational Research* 200(1), pp. 198-215.

Belton, V. 1986. A comparison of the analytical hierarchy process and a simple multi-attribute value function. *European journal of operational research* 26(1), pp. 7-21.

Benayoun, R., Roy, B., and Sussman, B. 1966. ELECTRE: une methode pour guider le choix en presence de points de vue multiples SEMA-METRA. *International Direction Scientifique* 49.

Benton, T. and Craib, I. 2001. *Philosophy of social science*. New York: Palgrave.

Berger, A.N. and Humphrey, D.B. 1997. Efficiency of Financial Institutions: International Survey and Directions for Future Research. *European Journal of Operational Research* 98(2), pp. 175-212.

Berrittella, M., Franca, L.L., and Zito, P. 2009. An analytic hierarchy process for ranking operating costs of low cost and full service airlines. *Journal of Air Transport Management* 15(5), pp. 249-255.

Beynon, M.J. 2002. An analysis of distributions of priority values from alternative comparison scales within AHP. *European Journal of Operational Research*. 140(1), pp. 104-117.

Benayoun, R., Roy, B., and Sussman, B. 1966. ELECTRE: Une methode pour guider le choix en presence de points de vue multiples. Sema (Metra International), *Direction Scientifi que, Note de Travail* , No. 49.

Berger, P. L., and Luckmann, T. 1966. *The social construction of reality: A treatise in the sociology of knowledge*. New York: Doubleday & Company.

Berrittella, M., Franca, L.L., and Zito, P. 2009. An analytical hierarchy process for ranking operating cost of low cost and full service airlines. *Journal of Air Transport Management* 15(5), pp. 249-255.

Beyth-Marom, R. how probable is probable? A numerical translation of verbal probability expressions. *Journal of forecasting* 1, pp. 257-269.

Bishop, M. and Thompson, D. 1992. Privatisation in the UK: internal organization and productive efficiency. *Annals of Public & Cooperative Economics* 63(2), pp. 171-189.

Brans J.-P. and Mareschal, B. 2005. PROMETHEE METHODS. In: Figueria J, Greco S, and Ehrgott, M. ed. *Multiple criteria decision analysis: State of the art surveys.* New York: Springer.

Boeing, 2012. *Current market outlook 2012* [online]. Settle: Boeing. Available at: http://www.boeing.com/commercial/cmo/ [Accessed: 19th July 2012].

Bojkovic, N., Anic, I. and Pejcic-Tarle, S. 2010. One solution for cross-country transport-sustainability evaluation using a modified ELECTRE method. *Ecological Economics* 69(5), pp. 1176-1186.

Bolloju, N. 2001. Aggregation of analytic hierarchy process models based on similarities in decision makers' preference. *European Journal of Operational Research* 128(3), pp. 499-508.

Bowlin, W. 1987. Evaluating the Efficiency of US Air Force Real-Property Maintenance Activities. *The Journal of the Operational Research Society*.38(2), pp. 127-136.

Brans, J.-P., and Mareschal, B. 2005. PROMETHEE METHODS. In: Figueria, J. Greco, S.,and Ehrgott, M. ed. *Multiple Criteria Decision Analysis: State of the Art Surveys*. New York: Springer.

Bureau, J. C, Fare, R, and Grosskopf, S. 1995. A comparison of 3 nonparametric measures of productivity growth in European and United-States agriculture. *Journal of Agricultural Economics* 46(3), pp. 309-26.

Burton, D. 2000. The use of case studies in social science research. In: Burton, D. ed. *Research Training for Social Scientists*. London: Sage.

Brugha, C.M. 2000. Relative measurement and the power function. *European journal of operational research 121*(3), pp. 627-640.

Bryman, A. 2008. Why do researchers integrate/combine/mesh/blend/mix/merge/ fuse quantitative and qualitative research. In: Bergman, M.M. ed. *Advances in mixed methods research*. London: Sage.

Bryman, A. and Bell, E. 2003. *Business Research Method*. Oxford: Oxford University Press.

Bryman, A. and Bell, E. 2007. *Business Research Method,* 2nd ed. Oxford: Oxford University Press.

Bryman, A. and Bell, E. 2011. *Business Research Method,* 3rd ed. Oxford: Oxford University Press.

Carney, M. and Mew, K. 2003. Airport governance reform: A strategic management perspective. *Journal of Air Transport Management* 9 (4), pp. 221-232.

Carmmone, Jr. F.J., Kara, A., and Zanakis, S.H. 1997. A Monte Carlo investigation of incomplete pairwise comparision matrices in AHP. *European Journal of Operational Research* 102(3), pp. 538-553.

Castelli, L. and Pellegrini, P. 2011. An AHP analysis of air traffic management with target windows. *Journal of Air Transport Management* 17(2), pp. 68-73.

Chang, Y. H., Yeh, C. H., and Liu, Y. L. 2006. Prioritizing management issues of moving dangerous goods by air transport. *Journal of Air Transport Management* 12(4), pp. 191-196.

Charnes, A., Cooper, W., and Rhodes, E. 1978. Measuring the efficiency of decision making units. *European Journal of Operational Research* 2(6), pp. 429-444.

Charnes, A., Cooper, W., Golany, B. Seiford, I. and Stutz, J. 1985. Foundations of data envelopment analysis for Pareto-Koopmans efficient empirical production functions. *Journal of Econometrics,* 30, pp. 91-107.

Charnes, A., Cooper, W., Lewin, A.Y., Seiford, L.M. 1994. *Data Envelopment Analysis: Theory, Methodology and Applications*. Boston: Kluwer Academic.

Charnes, A., and Neralic, L. 1990. Sensitivity Analysis of the Additive Model in Data Envelopment Analysis. *European Journal of Operations Research* 48(4), pp. 332-341.

Chen, T.Y., and Chen, L.H. 2007. DEA performance evaluation based on BSC indicators incorporated: the case of semiconductors industry. *International Journal of Productivity and Performance Management* 56(4), pp. 335-57.

Chen, C.-C., Chen, J., and Lin, P.-C. 2009. Identification of significant threats and errors affecting aviation safety in Taiwan using the analytic hierarchy process. *Journal of Air Transport Management* 15(5), pp. 261-263.

Chen, C.J. and Yen, Q.J. 2005. A comparative performance evaluation of Taiwan's high-tech industries. *International journal of business performance management* 7(1), pp. 16-33

Chi-Lok A.Y. and Zhang, A. 2009. Effects of competition and policy changes on Chinese airport productivity: An empirical investigation. *Journal of Air Transport Management* 15(4), pp. 166-174.

Chow, C.K.W. and Fung, M.K.Y. 2012. Estimating indices of airport productivity in grater china. *Journal of Air Transport Management* 24, pp. 12-17.

Churchill, G.A. 1976. *Marketing research: Methodological foundation*. Illinois: The Dyrden Press.

Churchill, G.A. and Iacobucci, D. 2002. *Marketing research: Methodological foundation* 8th ed. Orlando: Harcourt College Publishers.

Civil Aviation Administration of China, 2010. *The Civil Aviation Airport Production Statistics Communique′ of 2010* [Online] Beijing: CAAC. Available at: http://www.caac.gov.cn/E_Pub- WebApp/index.aspxS [Accessed: 10 April 2012].

Clark, D., Lotto, L. and Astuto, T. 1984. Effective schooling and school improvement: A comparative analysis of two lines to inquiry, *Educational Administration Quarterly* 20, pp. 41-68.

Coelli, T. J., Prasada Rao, D.S., O'Donnell, C. J., and Battese, G. E. 2005. *An Introduction to Efficiency and Productivity Analysi*s. 2nd ed. New York: Springer.

Comin, D. 2006. Total Factor Productivity. In: Durlauf, S. N. and Blume, L.E. ed. *The New Palgrave Dictionary of Economics*, 2nd ed. London: Palgrave Macmillan.

Competition Commission. 2008. *Working paper on benchmarking the operating performance of BAA airports*. [Online] London: Competition Commission. Available at: http://www.competitioncommission.org.uk/. [Accessed 30th May 2010].

Cooper, W. W., Seiford, L. M., and Tone, K. 2006. *Introduction to Data Envelopment Analysis and it uses*. New York: Springer.

Cullinane, K., Firth, M., Fung, M.K.Y, Gong, S.X.H., Law, J.S., and Zang, A. 2011. Development of air transport industry in the Asia-Pacific region. *Pacific economic review* 16(1), pp. 42-46.

Curi, C., Gitto, S. and Mancuso, P. 2010. The Italian airport industry in transition: a performance analysis. *Journal of Air Transport Management* 16(4), pp. 218-221.

Curi, C., Gitto, S. and Mancuso, P. 2011. New evidence on the efficiency of Italian airports: A bootstrapped DEA analysis. *Socio-Economic Planning Sciences* 45(2), pp. 84-93.

DeVaus, D. 2002. *Survey in Social Science*, 5th ed. London: Routeledge.

Denscombe, M. 2003. *The Good Research Guide for Small-Scale Social Research Projects*. 2nd ed. Maidenhead: Open University Press.

Dezin, N.K. and Lincoln, Y.S. 1994. Introduction: entire the field of qualitative research. In: Dezin, N.K. and Lincoln, Y.S. ed. *Handbook of qualitative research*. Thousand Oaks: Sage.

Doganis, R. 1992. *The Airport Business*. London: Routledge.

Doganis, R., Graham, A. and Lobbenberg, A. 1995. The economic performance of European airports. *Research Report* 3. London: University of Westminster.

Doganis, R. 2002. *Flying off course: The economics of international airlines*. 3rd London: Routledge.

Donegan, H.A., Dodd, F.J., McMaster, T.B., 1992. A new approach to AHP decision-making. *The Statistician* 41(3), pp. 295-302.

Doyle, J., Green, R. 1994. Efficiency and cross-efficiency in DEA: Derivations, meanings and uses. *Journal of the Operational Research Society* 45(5), pp. 567-578.

Dyer, J.S. 1990. Remarks on the Analytic hierarchy process. *Management science* 36(3), pp. 249-258.

Efron, B. and Tibshirani, R. 1994. *An Introduction to the Bootstrap*. New York: Chapman & Hall.

Ertay, T. Ruan, D., and Tuzkaya U.R. 2006. Integrating data envelopment analysis and analytic hierarchy for the facility layout design in manufacturing systems. *Information Sciences*, 176 (3), pp. 237-262.

Eisenhardt, K. M. 1989. Building theories from case study research. *Academy of Management Review* 14(4), pp. 532-550.

Escobar, M.T., Aguarón, J., and Moreno-Jiménez, J.M. 2004. A note on AHP group consistency for the row geometric mean priorization procedure. *European journal of operational research* 153(2), pp. 318-322.

Federal Aviation Administration. 2006. *Airport categories.* [Online]. Washington: Federal Aviation Administration. Available at: http://www.faa.gov/airports_airtraffic/airports/planning_capacity/passenger_allcargo_stats/categories/ [Accessed on October 15, 2011].

Federal Aviation Administration. 2011. *National Plan of Integrated Airport Systems (NPIAS)*, 2001–2005. Washington, D.C.: FAA.

Feng, Y. J., Lu, H., and Bi, K. 2004. An AHP/DEA method for measurement of the efficiency of R&D management activities in university. *International Transactions in Operational Research* 11, pp. 181-191.

Fernandes, E. and Pacheco, R.R. 2002. Efficient use of airport capacity. *Transportation Research Part A* 36(3), pp. 225-238.

Fodness, D. and Murry, B. 2007. Passengers' expectation of airport service quality. *Journal of Services Marketing*. 21, pp. 492-506.

Forman, E. and Peniwati, K. 1998. Aggregating individual judgments and priorities with the analytic hierarchy process. *European Journal of Operational Research*. 108(1), pp. 165-169.

Forsyth, P.J. 2000. Models of airport performance. In: Hensher, D.A. and Button, K.J. ed. *Handbook of Transport Modelling*. Oxford: ELSEVIER.

Forsyth, P.J. 2006. Airport competition: Regulatory issues and policy implications. In: Lee, D. ed. *Advances in Airline Economics: Competition policy and antitrust*. Oxford: Elsevier.

Francis, G., Humphreys, I. and Fry, J. 2002. The benchmarking of airport performance. *Journal of Air Transport Management* 8(4), pp. 239-247.

Freeling, A.N.S. 1983. *Belief and decision aiding.* PhD thesis, Cambridge University.

French, S. 1980. On *the methodology of decision analysis III: On various non Bayesian aids*. Notes in decision theory No. 89. Department of decision theory. University of Manchester.

Friedman, L., and Sinuany-Stern, Z. 1998. Combining ranking scales and selecting variables in the DEA context: the case of industrial branches. *Computers and Operations research* 25 (9), pp. 781-791

Fung, M.K.Y., Wan, K.K.H. Hui, Y.V. and Law, J.S. 2008. Productivity changes in Chinese airports 1995–2004. *Transportation Research Part E* 44(3), pp. 521-542.

Fung, M.K.Y. and Chow, C.K.W. 2011. Note on the productivity convergence of airports in China. *Pacific economic review* 16(1), pp. 120-133.

Gattoufi, S., Oral, M., and Reisman, A. 2004. Data envelopment analysis literature: a bibliography update (1951-2001). *Socio-Economic planning science* 38, pp. 159-229.

Getwick airport. (2011). *Getwick history.* [Online]. London: Gatwick Airport Limited. Available at: http://www.gatwickairport.com/. [Accessed: 25th January 2011].

Ghauri, P. N. and Grønhaug, K. 2002. *Research methods in business studies: A practical guide*. London: Pearson Education.

Giddens, A. 1974. *Positivism and Sociology.* London: Heinemann.

Gillen, D. and Lall, A. 1997. Developing measures of airport productivity and performance: an application of Data Envelopment Analysis. *Transportation Research Part E* 33(4), pp. 261-273.

Gillen, D. and Lall, A. 2001. Non-parametric measures of efficiency of U.S. airports. *International Journal of Transport Economics* 28(3), pp. 283-305.

Gillen, D. 2011. The evolution of airport ownership and governance. *Journal of Air Transport Management* 17(1), pp. 3-13

Giokas, D. 1991. Bank branch operating efficiency: A comparative application of DEA and the loglinear model. *Omega* 19(6), pp. 549-557.

Gitto, S. and Mancuso, P. 2012a. Two facts of airports business: A non-parametric analysis of the Italian airport industry. *Journal of Air Transport Management* 20, pp. 39-42.

Gitto, S. and Mancuso, P. 2012b. Bootstrapping the Malmquist indexes for Italian airports. International *Journal of production economics* 135, pp. 403-411.

Golany, B., Roll, Y., 1989. An application procedure for DEA. *Omega* 17(3), pp. 237-250.

Gong, S.X.H., Cullinane, K., and Firth, M. 2012. The impact of airport and seaport privatization on efficiency and performance: A review of the international evidence and implications for developing countries. Transport policy 24, pp. 37-47.

Gonzalez, M.M. and Trujillo, L. 2009. Efficiency measurement in the port industry: A survey of Empirical evidence. *Journal of Transport Economics and Policy* 43(2), pp. 157–192.

Graham, A. 2005. Airport benchmarking: a review of the current situation. *Benchmarking: An International Journal* 12(2), pp. 99–111.

Graham, A. 2006. Competition in airports. In: Papatheodorou, A. ed. *Rivalry and market power*. New York: I.B. Tauris & Co. Ltd.

Graham, A. 2008. *Managing airports: An international perspective*. 3rd. Oxford: Elsevier.

Graham, A. 2009. How important are commercial revenues to today's airports? *Journal of Air Transport Management* 15(3), pp. 106-111.

Graham, A. 2011. The objective and outcomes of airport privatisation. *Research in Transportation business & management* 1(1), pp. 3-14.

Greene, W. 2005. Fixed and random effects in stochastic frontier models. *Journal of Productivity Analysis* 23(1), pp. 7-32.

Grupo Ferrovial (2007). *Annual report 2006*. Madrid: Grupo Ferrovial.

Guo, J.Y., Liu, J., and Qiu, L. 2006. Research on supply chain performance evaluation: based on DEA/AHP model. *Proceedings of the IEEE Asia-Pacific Conference on Services Computing (APSCC'02)*.

Guba, E.G. and Lincoln, Y.S. 1994. Competing paradigms in qualitative research. In: Denzin, N.K. and Lincoln, Y.S. ed. *Handbook of qualitative research*. Thousand Oaks: Sage.

Guba, E.G. and Lincoln, Y.S. 2005. Paradigmatic Controversies, Contradictions, and Emerging Confluences. In: Denzin, N.K. and Lincoln, Y.S. ed. *Handbook of qualitative research*. 3rd ed. Thousand Oaks: Sage.

Hair, J. and Black, W. 2010. Multivariate data Analysis. 7th . London: Prentice Hall.

Hämäläinen, R.P. and Salo, A.A. 1997. The issue is understanding the weights, *Journal of multi-criteria decision analysis* 6, pp. 340-343.

Hamm, R.M. 1991. Selection of verbal probabilities: a solution for some problems of verbal probability expression. *Organization behaviour human decision process* 48, pp. 193-223.

Hamzaee, R.G. and Vasigh, B. 2000. A simple revenue-cost perspective on US airport operations. *Journal of Air Transport Management* 6(1), pp. 61-64.

Harker, P.T. and Vargas, L.G. 1987. The theory of ratio scale estimation: Saaty's analytic hierarchy process. *Management science* 33(11), pp. 1383-1403.

Harker, P.T. 1987. Alternative models of questioning in the analytic hierarchy process. *Mathematical modelling* 9(11), pp. 353-360.

Hershey, J.C., Kunreuther, H.C., and Schoemaker, P.J.H. 1982. Sources of bias in assessment procedures for utility functions. *Management science* 28(8), pp.936-939.

Ho, W. 2008. Integrated analytical hierarchy process and its applications-A literature review. *European journal of operational research* 186(1), pp. 211-228.

Hooper, P.G. and Hensher, D.A. 1997. Measuring total factor productivity of airports: An index number approach. *Transportation Research Part E* 33(4), pp. 249-259.

Hsu, K.H. 2005. Using balanced scorecard and fuzzy data envelopment analysis for multinational R&D project performance assessment. *Journal of America Academy of Business* 7(1), pp. 189-96.

Hu, F. H., Jiang, J., Liu, L., Sun, L. Y. and Ji, Y. C. 2010. A New Multi-perspective Framework for Multi-attribute Decision Making, *Expert Systems with Applications* 37(12), pp. 8575-82.

Huang, H. 2004. Estimation of technical inefficiencies with heterogeneous technologies. *Journal of Productivity Analysis* 21(3), pp. 277-296.

Humphreys, I. 1999. Privatisation and commercialisation change in UK airport ownership patterns. *Journal of Transport Geography* 7(2), pp. 121-134.

Humphreys, I. and Francis, G. 2002a. Airport privatisation. *British economy review* 31(2), pp. 51-56

Humphreys, I. and Francis, G. 2002b. Performance measurement: a review of airports. *International Journal of Transport Management* 1(2), pp. 79-85.

Hwang, C.L. and Yoon, K. 1981. *Multiple attribute decision making.* New York: Spring-Verlag.

International Civil Aviation Organisation (ICAO). 2006. *Airport Economics manual.* Montréal: ICAO.

Ison, S., Francis, G., Humphreys, I., and Page, R. 2011. UK regional airport commercialisation and privatisation: 25 years on. *Journal of transport geography* 19(6), pp. 1341-1349.

Jahanshahloo, G. R., Hosseinzadeh, Lotfi, F., and Moradi, M. 2004. Sensitivity and stability analysis in DEA with interval data. *Applied Mathematics and Computation* 156(6), pp. 463-477.

Jarach, D. 2005. *Airport Marketing*. Surrey: Ashgate.

Jensen, R.E. 1984. An alternative scaling method for priorities in hierarchical structures. *Journal of mathematical psychology* 28(3), pp. 317-332.

Jing-yuan, G., Jia, L., and Li, Q. 2006. Research on supply chain performance evaluation based on DEA/AHP model. *Proceedings of the 2006 IEEE Asia-Pacific Conference on Services Computing* (APSCC'06).

Jyoti, T. and Banwet, D. K. and Deshmukh, S. G. 2008. Evaluating performance of national R&D organizations using integrated DEA-AHP technique. *International Journal of Productivity and Performance Management* 57(5), pp. 370-388.

Joshi, G. 2000. *Overview of Privatization in South Asia*. New Delhi: ILO.

Kao, C. 2009. Efficiency decomposition in network data envelopment analysis: A relational model. *European journal of operational research* 192(3), pp. 949-962.

Kalirajan, K.P. and Obwona, M.B. 1994. Frontier production function: the stochastic coefficients approach. *Oxford Bulletin of Economics and Statistics* 56(1), pp. 87-96.

Kinnear, T.C. and Taylor, J.R. 1991. *Marketing Research: an applied approach.* London: McGraw-Hill.

Kok, M. and Lootsma, F.A. 1984. Pairwise comparsion methods in multiobjective programming, with applications in a long-term energy-planning model. *Technical report* 84(19). Delft university of technology.

Korpela, J., Lehmusvaara, A., and Nisonen, J. 2007. Warehouse operator selection by combining AHP and DEA methodologies. *International Journal of Production Economics* 108, pp. 135-42.

Kumbhakar, S., Park, B., Simar, L., and Tsionas, E. 2007. Nonparametric stochastic frontiers: a local maximum likelihood approach. *Journal of Econometrics* 137(1), pp. 1-27.

Lai, P., Potter, A. and Beynon, M. 2012. The development of benchmarking techniques in airport performance evaluation research. *Transportation Journal* 51 (3), pp. 305-337.

Lam, S., Low, J. and Tang, L. 2009. Operational efficiencies across Asia Pacific airports. *Transportation Research Part E* 45(4), pp. 654-665.

Lee, T. Z., and Tseng, Y. F. 2006. Explore the optimal Allocation Problem with AHP/DEA. *Asia Pacific Management Review* 11(6), pp. 389-392.

Legrady, K. Lootsma, F.A., Meisner, J. Schellemans, F. 1984. Multicriteria decision analysis to aid budget allocation. In: Grower, M. Woerzbick, A.P. ed. *Interactive Decision Analysis*. NEW York: Spring-Berlag

Leung, L.C., and Cao, D. 2000. On consistency and ranking of alternatives in Fuzzy AHP, *European journal of operational research* 124(1), pp. 102-113.

Levin, D.M. 1988. *The opening of vision: Nihilism and the postmodern situation.* London: Routledge.

Lewin, A. Y. and Minton, J. W. 1986. Determining Organizational Effectiveness: Another Look and an Agenda for Research. *Management Science* 32(5), pp. 514-538.

Lin, L. C. and Hong, C.H. 2006. Operational performance evaluation of international major airports: An application of data development analysis. *Journal of Air Transport Management* 12(6), pp. 342-351.

Lootsma, F.A. 1989. Fuzzy performance evaluation of nonlinear optimization methods, with sensitivity analysis of the final scores. *Journal of information and optimisation science* 10, pp.15-44.

Lozano, S. and Villa, G. 2007. Integer DEA models. How DEA models can handle integer inputs and outputs. In: Zhu, J., Cook, W. ed. *Modelling data irregularities and structural complexities in data envelopment analysis*. New York: Springer,

Lozano, S. and Gutierrez, E. 2011. Efficiency analysis and target setting of Spanish airports. *Network and Spatial Economics* 11(2), pp. 139-157.

Ma, J. and Zheng, X. 1991. 9/9-9/1 scale method of AHP. *Proceedings of the second international symposium on the AHP*, pp. 197-202.

May, T. 2001. *Social research: issues, methods and process.* 3rd ed. Buckingham: Open University Press.

Manataki, I.E. and Zografos, K.G. 2009. Assessing airport terminal performance using a system dynamics model. *Journal of Air Transport Management* 16(2), pp. 86-93.

Martin-Cejas, R.R. 2002. An approximation to the productive efficiency of the Spanish airports network through a deterministic cost frontier. *Journal of Air Transport Management* 8(4), pp. 233–238.

Martin, J.C. and Roman, C. 2001. An application of DEA to measure the efficiency of Spanish airports prior to privatization. *Journal of Air Transport Management* 7(3), pp. 149-157.

Martin, J.C. and Roman, C. 2006. A benchmarking analysis of Spanish commercial airports: A comparison between SMOP and DEA ranking methods. *Networks and Spatial Economics* 6(2), pp. 111-134.

Martin, J.C., Roman, C., and Voltes-Dorta, A. 2009. A Stochastic Frontier Analysis to estimate the relative efficiency of Spanish airports. *Journal of Productivity Analysis* 31(3), pp. 163-176.

Maylor, H. and Blackmon, K. 2005. *Researching Business and Management*, New York: Palgrave Macmillan.

McKenzie, G. 1997. *Understanding Social Research: Perspectives on Methodology and Practice.* London: Sage.

Mentzer, J.T. and Kahn, K.B. 1995. A framework of logistics research, *Journal of Business Logistics* 16(1), pp. 231-250.

Miller, D. 1983. *Handbook of Research Design and Social Measurement,* 4th ed. London: Longman.

Mon, D.L., Cheng, C.H. and Lin, J.C. 1994. Evaluating weapon system using fuzzy hierarchy process based on entropy weight. *Fuzzy Sets and Systems*. 62(2), pp. 127-134.

Morgan, P. 1995. The privatisation and the welfare state: a case for back to the future. In: Morgan, P. ed. *Privatisation and the welfare state: Implication for consumers and the workforce*. New York: Dartmouth.

Murillo-Melchor, C. 1999. An analysis of technical efficiency and productivity changes in Spanish airports using the Malmquist index. *International Journal of Transport Economics* 26(2), pp. 271-292.

Näslund, D. 2002. Logistics need qualitative research-especially action research, *International Journal of Physical Distribution & Logistics Management* 32(5), pp. 321-338.

Neufville, R. 1999. Airport privatization: issues for the United States. *Transportation Research Record: Journal of the Transportation Research Board* 1662, pp. 24-31.

Önü, S. and Soner, S. 2008. Transshipment site selection using AHP and TOPSIS approaches under fuzzy environment. *Waste Management* 28 (9), pp. 1552-1559.

Oum TH, Yu C. 1994. Economic efficiency of railways and implications for public policy. *Journal of Transport Economics & Policy*, 28(2), pp. 121–38.

Oum, T.H., Yu, C., and Fu, X. 2003. A comparative analysis of productivity performance of the world's major airports: summary report of the ATRS global airport benchmarking research report 2002. *Journal of Air Transport Management* 9(5), pp. 285-297.

Oum, T.H. and Yu, C. 2004. Measuring airports' operating efficiency: a summary of the 2003 ATRS global airport benchmarking report. *Transportation Research Part E* 40(6), pp. 515-532.

Oum, T.H., Adler, N. and Yu, C. 2006. Privatization, corporatization, ownership forms and their effect on the performance of the world's major airports. *Journal of Air Transport Management* 12(3), pp. 109-121.

Oum, T.H., Yan, J. and Yu, C. 2008. Ownership forms matter for airport efficiency: A stochastic frontier investigation of worldwide airports. *Journal of Urban Economics* 64(2), pp. 422-435.

Ozcan, Y. A. and McCue, M. J. 1996. Development of a Financial Performance Index for Hospitals: DEA Approach. *The journal of the operational research society* 47(1), pp. 18-26.

Pacheco, R.R. and Fernandes, E. 2003. Managerial efficiency of Brazilian airports. *Transportation Research Part A* 37(8), pp. 667-680.

Pallis, A.A., Vistounis, T.K. and De Langen, P.W. 2010. Port Economics, Policy and Management: Review of an Emerging Research Field. *Transport Review* 30(1), pp. 115-161.

Parker, D. 1999. The performance of BAA before and after privatisation: A DEA study. *Journal of Transport Economics and Policy* 33(2), pp. 133-146.

Pan, J. and Rahman, S. 1998. Multiattribute utility analysis with imprecise information: an enhanced decision support technique for the evaluation of electric generation expansion strategies. *Electric power systems research* 46(1), pp. 101-109.

Pathomsiri, S., Haghani, A. Dresner, M., and Windle, R.J. 2008. Impact of undesirable outputs on the productivity of US airports. *Transportation Research Part E* 44(2), pp. 235-259

Pels E, Nijkamp, P. and Rietveld, P. 2001. Relative efficiency of European airports. *Transport Policy* 8(3), pp. 183-192.

Pels E, Nijkamp, P. and Rietveld, P. 2003. Inefficiencies and scale economies of European airports operations. *Transportation Research Part E* 39(5), pp. 341-361.

Peng, J.L. and Zhan, C.X. 2011. A case study on evaluation of airport logistics competitiveness based on AHP. *Advanced material research* 159(2), pp. 307-312.

Perelman, S. and Serebrisky, T. 2012. Measuring the technical efficiency of airports in Latin America. *Utilities policy* 22(1), pp. 1-7.

Pirie, M. 1985. *Privatisation in Theory and Practice*. London: Adam Smith Institute.

Polit, D. F.,Beck, C. T., Hungler, B. P. 2001. *Essentials of nursing research: methods, appraisl and utilization*, 5th ed. Philadelphia: Lippincott Williams & Wilkins.

Pöyhönen, M.A., Hämäläinen, R.P., and Salo, A.A. 1997. An experiment on the numerical modelling of verbal ratio statement. *Journal of Multi-Criteria decision analysis* 6(1), pp. 1-10.

Ramanathan, R. 2001. A note on the use of the analytic hierarchy process for environmental impact assessment. *Journal of environmental management* 63(1), pp. 27-35.

Ramanathan, R. 2006. Data envelopment analysis for weight derivation and aggregation in the analytic hierarchy process. *Computers and Operations Research* 33 (5), pp. 1289-1307.

Reed, M. 1997. In praise of duality and dualism: rethinking agency and structure in organisational analysis. *Organisational Studies* 18, pp. 21-24.

Robson, C. 1993. *Real world research: A resource for social scientist and practitioner-researchers*. Oxford: Blackwell Publishers.

Robson,C. 2002. *Real World Research,* 2nd ed. Oxford: Blackwell.

Roy, B. 1971. Problems and methods with multiple objective functions. Mathematical programming 1(1), pp. 239-266.

Roy, B. 1991. The outranking approach and the foundations of ELECTRE methods. *Theory and decision* 31(1), pp. 49-73.

Roy, B. 2005. Paradigms and challenges. In Figueira, J., Greco, S., and Ehrgott, M. ed. 2005. *Multiple criteria decision analysis*. London: Springer.

Russell, R. 1985. Measures of technical efficiency. *Journal of economic theory* 35, pp. 109-126.

Saen, R. F., Memariani, A., and Lotfi, F. H. 2005. Determining relative efficiency of slightly non-homogeneous decision making units by data envelopment analysis: A case study in IROST. *Applied Mathematics and Computation* 165(2), pp. 313-328.

Saaty, R.W. 2003. *Decision making in complex environment*. Pittsburgh: Creative Decision Foundation.

Saaty, T.L. 1978. Exploring the interface between hierarchy, multiple objective and fuzzy sets. *Fuzzy sets and theory* 1, pp. 57-68.

Saaty, T.L. 1980. *The Analytic Hierarchy Process*. New York: McGraw-Hill.

Saaty, T.L. 1987. Rank generation, preservation and reversal in the analytic hierarchy decision process. *Decision science* 18, pp. 157-177.

Saaty, T.L. 1990. How to make a decision: the analytic hierarchy process. *European Journal of Operational Research* 48(1), pp. 9-26.

Saaty, T.L. 1996. *Decision Making with Dependence and Feedback: The Analytic Network Process.* Pittsburgh: RWS publication.

Saaty, T.L. 2008. Decision making with the analytic hierarchy process. *Journal of service science* 1(1), pp. 83-98.

Saaty, T.L. and Vargas, L.G. 1987. Uncertainty and rank order in the analytic hierarchy process. *European Journal of Operational Research* 32(1), pp. 107-117.

Salo, A.A. and Hämäläinen, R.P. 1993. On the measurement of preferences in the analytic hierarchy process. *Research report A47 system analysis laboratory*. Helsinki: Helsinki University.

Sarkis, J. 2000. An analysis of the operational efficiency of major airports in the United States. *Journal of Operations Management* 18(3), pp. 335-351.

Sarkis, J. and Talluri, S. 2004. Performance based clustering for benchmarking of US airports, *Transportation Research Part A* 38(5), pp. 329-346.

Saunders, M., Lewis, P. and Thornhill, A. 2000. *Research Methods for Business Students.* 3th ed. London: Prentice Hall.

Saunders, M., Lewis, P. and Thornhill, A. 2007. *Research Methods for Business Students.* 4th ed. London: Prentice Hall.

Saunders, M., Lewis, P. and Thornhill, A. 2009. *Research Methods for Business Students.* 5th ed. London: Prentice Hall.

Sayer, A. 2000. *Realism and Social Science.* London: Sage.

Schoner, B. and Wedley, W.C. 1989. Alternative scales in AHP. In: Lockett, A.G. and Islei, G. ed. *Improving decisions in organizations LNEM 335*. Berlin: Springer.

Scotti, D., Malighetti, P. Martini, G. and Volta, N. 2012.The impact of airport competition efficiency: A stochastic frontier analysis applied to Italian airports. *Journal of Air Transport Management* 22, pp. 9-15.

Shahroudi, K., Taleghani, M., and Mohammadi, G. 2012. Application of two-stage DEA technique for efficiencies measuring of private insurance companies in Iran. *International journal of applied operational research* 1(3), pp. 91-104

Shearman, P. 1992. *Air transport: Strategic issues in planning and development.* London: Pitman Publishing.

Sinuany-Stern, Z., Mehrez, A., and Hadad, Y. 2000. An AHP/DEA methodology for ranking decision making units. *International Transactions in Operational Research* 7(2), pp. 109-124.

Smith, P. K. 2000. Philosophy of science and its relevance for the social science. In: Burton, D. ed. *Research Training for Social Scientist*. London: SAGE Publication.

Spens, K.M. and Kovács, G. 2005. A content analysis of research approaches in logistics research, *International Journal of Physical Distribution and Logistics Management.* 36(5), pp. 374-390.

Starkie, D. 2008. *Aviation market*. Surrey: Ashgate.

Takamura, Y. & Tone, K. 2003. A Comparative Site Evaluation Study for Relocating Japanese Government Agencies Out of Tokyo. *Socio-Economic Planning Sciences* 37(2), pp. 85-102.

Timmermanns, D. 1994. The roles of experience and domain of expertise in using numerical and verbal probability terms in medical decisions. *Medical decision making* 14, pp. 146-156.

Thompson, G. 1990. *The political economy of the new right*. London: Printer.

Tovar, B. and Martin-Cejas, R.R. 2010. Technical efficiency and productivity changes in Spanish airports: A parametric distance function approach. *Transportation Research Part E* 46(2), pp. 249-260.

Triantaphyllou, E.V. 2000. *Multi-criteria decision-making methods: A comparative study*. London: Springer.

Triantaphyllou, E.V., Loostma, F.A., Pardalos, P.M., and Mann, S.H. 1994. On the evaluation and application of different scales for quantifying pairwise comparison in Fuzzy sets. *Journal of Multi-Criteria Decision Analysis*. 3(1), pp. 133-155.

Tsai, M. C. and Su, Y. S. 2002. Political risk assessment on air logistics hub developments in Taiwan. *Journal of Air Transport Management* 8(6), pp. 373-380.

Tsekeris, T. 2011 Greek airports: Efficiency measurement and analysis of determinants. *Journal of Air Transport Management* 17(3), pp. 140-142.

Tsionas, E. 2002. Stochastic frontier models with random coefficients. *Journal of Applied Econometrics* 17(2), pp. 127-147.

Turner, J. R. 2005. The role of pilot studies in reducing risk on projects and programmes. *International Journal of Project Management* 23(1), pp. 1-6

Ülkü, T. 2009. *Efficiency of German airports and influencing factors*, MSc Thesis. Humboldt University.

Varian, H. 2005. Bootstrap Tutorial. *Mathematica Journal* 9 (4), pp. 768-75.

Vasigh, B. and Gorjidooz, J. 2006. Productivity analysis of public and private airports: a casual investigation. *Journal of Air Transportation* 11(3), pp. 144-163.

Vickers, J. and Yarrow, G. 1988. *Privatization: An economic analysis*. Boston: MIT press.

Vickers, J. and Yarrow, G. 1991. Economic perspectives on privatization. Journal economic perspectives 5, pp. 111-132.

Wagner, S.M. and Kemmerling, R. 2010. Handling nonresponse in logistics research, *Journal of Business Logistics.* 31(2), pp. 357-381.

Wanke, P.F 2012a. Efficiency of Brazil's airports: Evidence from bootstrapped DEA and FDH estimates. *Journal of Air Transport Management* 23, pp. 47-53.

Wanke, P.F 2012b. Capacity shortfall and efficiency in Brazilian airports: Evidence from bootstrapped DEA estimates. *Socio-Economic planning sciences* 46(3), pp. 216-229.

Wang R.-T., Ho, C.-T. Feng, C.-M., and Yang, Y.-K. 2004. A comparative analysis of the operational performance of Taiwan's major airports. *Journal of Air Transport Management* 10(5), pp. 353-360.

Wang, Y.M., Liu, J., and Elhag, M.S. 2008. An integrated AHP-DEA methodology for bridge risk assessment. *Computer & Industrial Engineering* 54(3), pp. 513-525.

Wells, A. T. and Young, S. B. 2004. *Airport planning and management*. 5th ed. London: McGraw-Hill.

Wenseveen, J. G. 2007. Air transportation: a management perspective sixth ed. Surrey: Ashgate.

Woo, S.-H., and Pettit, S.J. and Kwak, D.-K. 2010. *Trends and themes in port research since 1980– a decadal approach*. International Association of Maritime Economists Conference 2010, Lisbon.

Wragg, D. 2009. *The world's top 500 airports*. Somerset: Haynes publishing.

Xing, T.P. and Tseng, G.X. 2002. Accessing efficiency of criminal investigation and crime prevention in Taiwan police department: an application of DEA and AHP. *Journal of Information, Technology and Society* 1, pp. 33-56.

Yang, H.-H. 2010. Measuring the efficiencies of Asia-Pacific international airports- Parametric and non-parametric evidence. *Computer & Industrial Engineering* 59(4), pp. 697–702.

Yang, X and Houng, Y. U. 2010. Deregulatory reform of China's airports. *East Asia policy* 2(2), pp. 62-72.

Yang,T. and Kuo, C. 2003. A hierarchical AHP/DEA methodology for the facilities layout design problem. *European Journal of Operational Research*, 147 (1), pp. 128–136

Yang, X., Tok, S. K., and Su, F. 2008.The privatization and commercialization of China's airports. *Journal of Air Transport Management* 14(5), pp. 243-251.

Yeh, C. H., Deng, H. and Pan, H. 1999. Multi-Criteria Analysis for Dredger Dispatching under Uncertainty. *Journal of the Operational Research Society* 50, pp. 35-43.

Yeh C.H., Deng H., and ChangY. 2000. Fuzzy multicriteria analysis for performance evaluation of bus companies. *European Journal of Operational Research.* 126(3), pp. 459-473.

Yoo, K. E. and Choi, Y. C. 2006. Analytic hierarchy process approach for identifying relative importance of factors to improve passenger security checks at airports. *Journal of Air Transport Management* 12(3), pp.135-142.

Yoshida, Y. 2004. Endogenous-weight TFP measurement: Methodology and its Application to Japanese-airport benchmarking. *Transportation Research Part E* 40(2), pp. 151-182.

Yoshida, Y and Fujimoto, H. 2004. Japanese-airport benchmarking with the DEA and endogenous-weight TFP methods Testing the criticism of overinvestment in Japanese regional airports, *Transportation Research Part E* 40(6), pp. 533-546.

Yu, M.-M. 2004. Measuring physical efficiency of domestic airports in Taiwan with undesirable outputs and environmental factors. *Journal of Air Transport Management* 10(5), pp. 295-303.

Yu, M.-M., Hsu, S.-H., Chang, C.-C., and Lee, D.-H. 2008. Productivity growth of Taiwan's major domestic airports in the presence of aircraft noise. *Transportation Research Part E* 44(3), pp. 543-554.

Yu, M.-M. 2010. Assessment of airport performance using the SBM-NDEA model. *Omega* 38(6), pp. 440-452.

Zeleny, M. 1983. *Multiple criteria decision making*. New York: McGraw Hill.

Zhang, A., Yuen, A., 2008. Airport policy and performance in Mainland China and Hong Kong. In: Winston, C., de Rus, G. ed. *Aviation Infrastructure Performance: A Study in Comparative Political Economy*. Washington, D.C.: Brookings Institution Press.

Zhang, B., Wang, J., Liu, C. and Zhao, Y. 2012. Evaluating the technical efficiency of Chinese airport airside activities. *Journal of Air Transport Management* 20, pp. 23-27.

Zhang, Y. and Bartels, R. 1998. The effect of sample size on the mean efficiency in DEA with an application to electricity distribution in Australia, Sweden and New Zealand. *Journal of productivity* 9(3), pp.187-204.

Zhu, J. 2009. *Quantitative models for performance evaluation and benchmarking*, 2nd ed. New York : Springer.

Appendix III: Relative weighted input and output variables scores

Table 1: Relative weighted input and output scores (scale e^{1-9})

	Relative Weighted Input Score Obtained by the DMUs						Relative Weighted Output Score Obtained by the DMUs			
e^{1-9} weights	0.0124	0.1153	0.0825	0.0971	0.0490	0.6436	0.2670	0.1644	0.0628	0.5057
	Number of Employees	Number of Gates	Number of Runways	Size of Terminal Area	Length of Runway	Operational Expenditure	Number of Passengers	Amount of Freight and Mail	Aircraft Movement	Total Revenues
Amsterdam (AMS)	0.1777	4.1054	8.25	4.1586	3.8864	34.2657	18.8854	7.5803	5.0110	18.6599
Barcelona (BCN)	0.0392	4.4111	4.125	1.0904	3.4144	10.0944	12.0281	0.5040	3.6065	10.1082
Frankfurt (FRA)	1.2400	7.5993	4.125	5.6208	4.7922	64.3600	21.2892	10.2079	5.4495	18.6801
Istanbul (IST)	0.1206	1.3976	4.125	2.2378	3.3150	5.9810	11.3611	3.7049	2.8553	4.4961
London (LGW)	0.1506	4.6731	1.375	1.4229	3.9727	20.3177	13.6231	0.5433	2.9577	13.8381
London (LHR)	0.3801	11.5300	2.75	2.5631	4.5286	63.2802	26.7000	7.1865	5.3700	50.5700
Madrid (MAD)	0.0549	3.3193	5.50	2.1078	4.6281	20.1884	20.2456	1.5907	5.2696	20.2167
Munich (MUC)	0.5099	8.7349	2.75	3.2179	4.7922	36.9631	13.7577	1.3271	4.8495	21.0410
Paris (CDG)	0.2658	5.4156	5.50	3.8123	4.1381	37.7061	24.2389	9.8640	6.2800	33.3936
Paris (ORY)	0.2277	4.4547	4.125	2.6102	3.7415	17.3008	10.4362	0.6769	2.5820	14.3054
Rome (FCO)	0.2259	3.7560	5.50	2.0024	4.4052	16.6058	14.0265	0.6645	3.8888	19.0985
Zurich (ZRH)	0.0864	2.9262	4.125	0.9739	3.7942	13.9626	10.9494	1.8745	3.0849	11.6485
Bangkok (BKK)	0.2236	5.2410	2.75	3.9557	4.6125	15.0198	18.6871	6.2469	3.4937	20.0504
Beijing (PEK)	0.1354	5.2410	2.75	9.7100	4.3130	17.9825	22.2731	6.6133	4.8198	10.0066
Guangzhou (CAN)	0.2399	3.2319	2.75	2.2483	4.4328	8.1924	13.3130	4.6522	2.3682	4.2477
Hong Kong (HKG)	0.0779	4.6295	2.75	4.9885	4.5526	14.7831	18.9929	16.4400	3.3205	12.9456
Incheon (ICN)	0.0643	3.9307	4.125	4.2156	4.5921	13.7892	11.9345	11.7194	2.3682	13.6289
Kuala Lumpur (KUL)	0.1087	4.6295	2.75	3.3683	4.9000	8.9276	10.9614	3.2275	2.3522	6.4607
Osaka (KIX)	0.0267	2.2711	2.75	2.3186	4.4927	15.9380	6.3764	4.0932	1.4976	18.0399
Tokyo (HRT)	0.0496	3.7997	2.75	5.5485	3.8936	38.5721	13.0020	10.1563	2.1687	33.2237
Shanghai (PVG)	0.4437	4.2801	4.125	5.7895	4.4723	7.3754	11.2429	12.5864	2.9810	15.4322
Singapore (SIN)	0.0962	4.4547	4.125	7.3283	4.2926	13.9974	9.1090	2.0102	2.0787	11.3934
Shenzhen (SZX)	0.2755	2.4020	1.375	1.0680	4.0734	3.3207	8.5213	2.8917	2.1083	4.5156
Sydney (SYD)	0.0211	2.8388	4.125	2.7225	3.5678	4.7444	13.0999	2.2726	3.3538	8.6798

Table 2: Relative weighted input and output scores (scale 2^{1-9})

	Relative Weighted Input Score Obtained by the DMUs						Relative Weighted Output Score Obtained by the DMUs			
2^{1-9} weights	0.0051	0.1108	0.0695	0.0869	0.0336	0.6941	0.2991	0.1527	0.0402	0.5079
	Number of Employees	Number of Gates	Number of Runways	Size of Terminal Area	Length of Runway	Operational Expenditure	Number of Passengers	Amount of Freight and Mail	Aircraft Movement	Total Revenues
Amsterdam (AMS)	0.0731	3.9451	6.9500	3.7218	2.6650	36.9544	21.1559	7.0409	3.2077	18.7411
Barcelona (BCN)	0.0161	4.2390	3.4750	0.9759	2.3413	10.8864	13.4741	0.4682	2.3086	10.1522
Frankfurt (FRA)	0.5100	7.3027	3.4750	5.0304	3.2861	69.4100	23.8487	9.4814	3.4884	18.7613
Istanbul (IST)	0.0496	1.3430	3.4750	2.0027	2.2731	6.4503	12.7270	3.4412	1.8278	4.5157
London (LGW)	0.0620	4.4907	1.1583	1.2734	2.7242	21.9119	15.2610	0.5047	1.8933	13.8983
London (LHR)	0.1563	11.0800	2.3167	2.2939	3.1053	68.2455	29.9100	6.6751	3.4375	50.7900
Madrid (MAD)	0.0226	3.1897	4.6333	1.8864	3.1735	21.7724	22.6796	1.4775	3.3732	20.3047
Munich (MUC)	0.2097	8.3940	2.3167	2.8799	3.2861	39.8634	15.4117	1.2327	3.1043	21.1325
Paris (CDG)	0.1093	5.2043	4.6333	3.4118	2.8375	40.6647	27.1530	9.1620	4.0200	33.5389
Paris (ORY)	0.0936	4.2809	3.4750	2.3360	2.5656	18.6583	11.6908	0.6288	1.6528	14.3676
Rome (FCO)	0.0929	3.6094	4.6333	1.7921	3.0207	17.9088	15.7128	0.6172	2.4893	19.1815
Zurich (ZRH)	0.0355	2.8120	3.4750	0.8716	2.6017	15.0582	12.2658	1.7411	1.9747	11.6992
Bangkok (BKK)	0.0920	5.0364	2.3167	3.5401	3.1628	16.1984	20.9338	5.8023	2.2364	20.1376
Beijing (PEK)	0.0557	5.0364	2.3167	8.6900	2.9575	19.3935	24.9509	6.1426	3.0853	10.0501
Guangzhou (CAN)	0.0987	3.1058	2.3167	2.0122	3.0396	8.8352	14.9135	4.3211	1.5159	4.2661
Hong Kong (HKG)	0.0321	4.4488	2.3167	4.4645	3.1218	15.9431	21.2763	15.2700	2.1256	13.0019
Incheon (ICN)	0.0264	3.7773	3.4750	3.7728	3.1489	14.8711	13.3693	10.8853	1.5159	13.6882
Kuala Lumpur (KUL)	0.0447	4.4488	2.3167	3.0145	3.3600	9.6281	12.2792	2.9978	1.5057	6.4889
Osaka (KIX)	0.0110	2.1824	2.3167	2.0750	3.0807	17.1886	7.1430	3.8019	0.9587	18.1184
Tokyo (HRT)	0.0204	3.6514	2.3167	4.9656	2.6699	41.5986	14.5652	9.4335	1.3882	33.3682
Shanghai (PVG)	0.1825	4.1130	3.4750	5.1813	3.0667	7.9541	12.5945	11.6907	1.9082	15.4993
Singapore (SIN)	0.0396	4.2809	3.4750	6.5585	2.9435	15.0957	10.2042	1.8671	1.3307	11.4430
Shenzhen (SZX)	0.1133	2.3083	1.1583	0.9558	2.7932	3.5813	9.5458	2.6859	1.3496	4.5352
Sydney (SYD)	0.0087	2.7280	3.4750	2.4365	2.4465	5.1166	14.6749	2.1109	2.1469	8.7175

Table 3: Relative weighted input and output scores (scale 9/9-9/1)

	Relative Weighted Input Score Obtained by the DMUs						**Relative Weighted Output Score Obtained by the DMUs**			
9/9-9/1 weights	0.0522	0.1103	0.1013	0.1066	0.0825	0.5436	0.1971	0.1719	0.1286	0.4976
	Number of Employees	Number of Gates	Number of Runways	Size of Terminal Area	Length of Runway	Operational Expenditure	Number of Passengers	Amount of Freight and Mail	Aircraft Movement	Total Revenues
Amsterdam (AMS)	0.7480	3.9278	10.1300	4.5657	6.5439	28.9413	13.9409	7.9263	10.2610	27.5770
Barcelona (BCN)	0.1650	4.2201	5.0650	1.1971	5.7486	8.5236	8.8794	0.5277	7.3855	5.5781
Frankfurt (FRA)	5.2200	7.2699	5.0650	6.1711	8.0685	54.3600	15.7148	10.6733	11.1599	36.2153
Istanbul (IST)	0.5074	1.3368	5.0650	2.4571	5.5811	5.0500	8.3866	3.8746	5.8474	4.8864
London (LGW)	0.6342	4.4705	1.6887	1.5617	6.6891	17.1615	10.0560	0.5673	6.0571	14.6991
London (LHR)	1.5999	11.0300	3.3763	2.8142	7.6247	53.4468	19.7100	7.5137	10.9966	49.7600
Madrid (MAD)	0.2312	3.1755	6.7537	2.3143	7.7921	17.0527	14.9461	1.6640	10.7908	11.1512
Munich (MUC)	2.1465	8.3563	3.3763	3.5327	8.0685	31.2189	10.1566	1.3872	9.9305	23.5464
Paris (CDG)	1.1192	5.1808	6.7537	4.1851	6.9671	31.8495	17.8927	10.3140	12.8600	30.4382
Paris (ORY)	0.9584	4.2620	5.0650	2.8654	6.2997	14.6120	7.7046	0.7082	5.2880	12.6042
Rome (FCO)	0.9511	3.5936	6.7537	2.1981	7.4168	14.0249	10.3537	0.6945	7.9629	16.3312
Zurich (ZRH)	0.3638	2.7994	5.0650	1.0692	6.3880	11.7907	8.0831	1.9597	6.3168	13.5895
Bangkok (BKK)	0.9412	5.0142	3.3763	4.3429	7.7657	12.6876	13.7950	6.5322	7.1540	12.6241
Beijing (PEK)	0.5700	5.0142	3.3763	10.6600	7.2617	15.1882	16.4421	6.9155	9.8701	9.6634
Guangzhou (CAN)	1.0101	3.0917	3.3763	2.4678	7.4630	6.9200	9.8274	4.8648	4.8495	6.5186
Hong Kong (HKG)	0.3278	4.4285	3.3763	5.4760	7.6651	12.4865	14.0197	17.1900	6.7991	19.2870
Incheon (ICN)	0.2704	3.7601	5.0650	4.6286	7.7319	11.6493	8.8104	12.2548	4.8495	16.7592
Kuala Lumpur (KUL)	0.4578	4.4285	3.3763	3.6980	8.2500	7.5397	8.0910	3.3744	4.8174	5.0307
Osaka (KIX)	0.1128	2.1729	3.3763	2.5456	7.5644	13.4595	4.7067	4.2803	3.0671	16.5054
Tokyo (HRT)	0.2088	3.6355	3.3763	6.0911	6.5555	32.5779	9.5988	10.6200	4.4406	31.5031
Shanghai (PVG)	1.8682	4.0943	5.0650	6.3555	7.5298	6.2297	8.2999	13.1607	6.1046	8.2950
Singapore (SIN)	0.4051	4.2620	5.0650	8.0451	7.2270	11.8233	6.7251	2.1023	4.2567	15.8635
Shenzhen (SZX)	1.1599	2.2975	1.6887	1.1726	6.8582	2.8050	6.2914	3.0237	4.3171	3.7370
Sydney (SYD)	0.0887	2.7156	5.0650	2.9891	6.0068	40.0633	9.6697	2.3757	6.8672	13.3158

Table 4: Relative weighted input and output scores (scale 10/10-18/2)

	Relative Weighted Input Score Obtained by the DMUs						Relative Weighted Output Score Obtained by the DMUs			
10/10-18/2 weights	0.0417	0.1128	0.0986	0.1058	0.0786	0.5626	0.2111	0.1722	0.1140	0.5027
	Number of Employees	Number of Gates	Number of Runways	Size of Terminal Area	Length of Runway	Operational Expenditure	Number of Passengers	Amount of Freight and Mail	Aircraft Movement	Total Revenues
Amsterdam (AMS)	0.5976	4.0164	9.8600	4.5312	6.2342	29.9532	14.9315	7.9400	9.0964	18.5492
Barcelona (BCN)	0.1318	4.3155	4.9300	1.1881	5.4770	8.8239	9.5098	0.5279	6.5468	10.0482
Frankfurt (FRA)	4.1700	7.4345	4.9300	6.1245	7.6871	56.2600	16.8320	10.6922	9.8925	18.5692
Istanbul (IST)	0.4055	1.3672	4.9300	2.4383	5.3175	5.2282	8.9825	3.8807	5.1833	4.4695
London (LGW)	0.5065	4.5718	1.6433	1.5504	6.3726	17.7606	10.7710	0.5691	5.3690	13.7560
London (LHR)	1.2782	11.2800	3.2867	2.7928	7.2643	55.3161	21.1100	7.5275	9.7481	50.2700
Madrid (MAD)	0.1847	3.2473	6.5733	2.2967	7.4238	17.6476	16.0069	1.6662	9.5658	20.0968
Munich (MUC)	1.7147	8.5455	3.2867	3.5063	7.6871	32.3112	10.8774	1.3901	8.8033	20.9162
Paris (CDG)	0.8940	5.2982	6.5733	4.1539	6.6378	32.9606	19.1641	10.3320	11.4000	33.1955
Paris (ORY)	0.7656	4.3581	4.9300	2.8440	6.0017	15.1234	8.2512	0.7091	4.6871	14.2205
Rome (FCO)	0.7596	3.6746	6.5733	2.1818	7.0663	14.5159	11.0899	0.6960	7.0593	18.9852
Zurich (ZRH)	0.2906	2.8628	4.9300	1.0612	6.0862	12.2054	8.6570	1.9634	5.5999	11.5794
Bangkok (BKK)	0.7519	5.1273	3.2867	4.3101	7.3988	13.1295	14.7747	6.5433	6.3421	19.9315
Beijing (PEK)	0.4553	5.1273	3.2867	10.5800	6.9184	15.7193	17.6099	6.9270	8.7493	9.9472
Guangzhou (CAN)	0.8068	3.1618	3.2867	2.4498	7.1105	7.1613	10.5257	4.8729	4.2989	4.2225
Hong Kong (HKG)	0.2621	4.5291	3.2867	5.4355	7.3027	12.9226	15.0165	17.2200	6.0277	12.8688
Incheon (ICN)	0.2162	3.8455	4.9300	4.5933	7.3661	12.0537	9.4358	12.2754	4.2989	13.5481
Kuala Lumpur (KUL)	0.3657	4.5291	3.2867	3.6701	7.8600	7.8041	8.6664	3.3807	4.2699	6.4224
Osaka (KIX)	0.0899	2.2218	3.2867	2.5263	7.2066	13.9321	5.0414	4.2874	2.7186	17.9329
Tokyo (HRT)	0.1668	3.7173	3.2867	6.0456	6.2457	33.7176	10.2799	10.6382	3.9368	33.0266
Shanghai (PVG)	1.4923	4.1872	4.9300	6.3082	7.1739	6.4472	8.8890	13.1836	5.4114	15.3407
Singapore (SIN)	0.3235	4.3581	4.9300	7.9849	6.8857	12.2358	7.2019	2.1055	3.7735	11.3258
Shenzhen (SZX)	0.9264	2.3500	1.6433	1.1636	6.5340	2.9028	6.7373	3.0289	3.8272	4.4888
Sydney (SYD)	0.0709	2.7772	4.9300	2.9664	5.7230	4.1473	10.3573	2.3804	6.0881	8.6283

Table 5: Relative weighted input and output scores (scale ø mapping)

	Relative Weighted Input Score Obtained by the DMUs						**Relative Weighted Output Score Obtained by the DMUs**			
ø mapping weights	0.0613	0.1087	0.1009	0.1050	0.0886	0.5355	0.1919	0.1711	0.1354	0.5016
	Number of Employees	Number of Gates	Number of Runways	Size of Terminal Area	Length of Runway	Operational Expenditure	Number of Passengers	Amount of Freight and Mail	Aircraft Movement	Total Revenues
Amsterdam (AMS)	0.8785	3.8704	10.090	4.4970	7.0273	28.5104	13.5735	7.8893	10.8040	18.5087
Barcelona (BCN)	0.1938	4.1586	5.0450	1.1792	6.1738	8.3989	8.6449	0.5246	7.7758	10.0262
Frankfurt (FRA)	6.1300	7.1643	5.0450	6.0781	8.6651	53.5500	15.3011	10.6239	11.7495	18.5286
Istanbul (IST)	0.5961	1.3176	5.0450	2.4199	5.9941	4.9764	8.1655	3.8559	6.1563	4.4597
London (LGW)	0.7446	4.4056	1.6817	1.5387	7.1833	16.9051	9.7913	0.5655	6.3769	13.7259
London (LHR)	1.8789	10.8700	3.3633	2.7716	8.1885	52.6516	19.1900	7.4794	11.5780	50.1600
Madrid (MAD)	0.2715	3.1293	6.7267	2.2793	8.3683	16.7975	14.5510	1.6556	11.3615	20.0528
Munich (MUC)	2.5207	8.2349	3.3633	3.4797	8.6651	30.7548	9.8880	1.3812	10.4558	20.8704
Paris (CDG)	1.3142	5.1056	6.7267	4.1225	7.4823	31.3729	17.4211	10.2660	13.5400	33.1229
Paris (ORY)	1.1254	4.1997	5.0450	2.8225	6.7652	14.3949	7.5007	0.7045	5.5670	14.1894
Rome (FCO)	1.1166	3.5410	6.7267	2.1653	7.9653	13.8167	10.0812	0.6916	8.3844	18.9436
Zurich (ZRH)	0.4272	2.7587	5.0450	1.0531	6.8606	11.6175	7.8696	1.9509	6.6511	11.5540
Bangkok (BKK)	1.1053	4.9410	3.3633	4.2775	8.3401	12.4971	13.4309	6.5015	7.5326	19.8879
Beijing (PEK)	0.6693	4.9410	3.3633	10.5000	7.7986	14.9621	16.0083	6.8828	10.3917	9.9254
Guangzhou (CAN)	1.1861	3.0469	3.3633	2.4313	8.0152	6.8164	9.5684	4.8418	5.1059	4.2132
Hong Kong (HKG)	0.3853	4.3645	3.3633	5.3944	8.2318	12.3001	13.6507	17.1100	7.1593	12.8406
Incheon (ICN)	0.3178	3.7057	5.0450	4.5586	8.3032	11.4731	8.5776	12.1970	5.1059	13.5184
Kuala Lumpur (KUL)	0.5375	4.3645	3.3633	3.6424	8.8600	7.4281	7.8782	3.3591	5.0715	6.4084
Osaka (KIX)	0.1322	2.1411	3.3633	2.5072	8.1235	13.2610	4.5829	4.2600	3.2290	17.8937
Tokyo (HRT)	0.2453	3.5822	3.3633	5.9999	7.0403	32.0934	9.3449	10.5702	4.6758	32.9543
Shanghai (PVG)	2.1937	4.0351	5.0450	6.2605	8.0866	6.1366	8.0805	13.0994	6.4272	15.3071
Singapore (SIN)	0.4755	4.1997	5.0450	7.9245	7.7617	11.6464	6.5469	2.0921	4.4819	11.3010
Shenzhen (SZX)	1.3618	2.2645	1.6817	1.1548	7.3653	2.7630	6.1245	3.0095	4.5457	4.4790
Sydney (SYD)	0.1042	2.6763	5.0450	2.9440	6.4511	3.9475	9.4153	2.3652	7.2310	8.6094

Appendix IV: The weight distribution of variables in AHP/DEA model

Table 1: The weight distribution of variables in AHP/DEA model (1-9 and e^{1-9})

	1-9										e^{1-9}									
DMUs	Number of Employees	Number of Gates	Number of Runways	Size of Terminal Area	Length of Runway	Operational Expenditure	Number of Passengers	Amount of Freight and Mail	Aircraft Movement	Total Revenues	Number of Employees	Number of Gates	Number of Runways	Size of Terminal Area	Length of Runway	Operational Expenditure	Number of Passengers	Amount of Freight and Mail	Aircraft Movement	Total Revenues
1	0.1511	0.5355	0	0	0.3134	0	0.0499	0.2373	0.7128	0	0.1546	0.5321	0	0.0112	0.3021	0	0	0.2473	0.7527	0
2	0.4963	0	0	0.2889	0	0.2148	1	0	0	0	0.4693	0	0	0.5307	0	0	1	0	0	0
3	0	0	0.2924	0	0	0	0	0.2932	0.7068	0	0	0	0.2924	0	0	0	0	0.2932	0.7068	0
4	0.3089	0.6911	0	0	0	0	1	0	0	0	0	0.4191	0.5809	0	0	0	0.9911	0.0089	0	0
5	0.6148	0	0.3514	0.0338	0	0	0.1713	0	0.6692	0.1595	0	0	0.0656	0.8236	0	0.1108	1	0	0	0
6	0	0	0.3657	0	0	0.6343	0	0.0642	0.3520	0.5839	0.1909	0	0.8091	0	0	0	0.3647	0.1174	0.5179	0
7	0.4417	0.5583	0	0	0	0	1	0	0	0	0.3004	0	0.3646	0	0.3351	0	1	0	0	0
8	0	0	0.3326	0.0722	0.3109	0.2843	0	0	0.9512	0.0488	0	0	0.4298	0.0617	0.3157	0.1928	0	0	1	0
9	0	0.3743	0.4029	0.0817	0.1411	0	1	0	0	0	0	0.3743	0.4029	0.0817	0.1411	0	1	0	0	0
10	0	0.1324	0.0934	0.2000	1.0823	0.7198	0	0	0	1	0	0.1324	0.0934	0.2000	1.0824	0.7198	0	0	0	1
11	0	0.0202	0	0.5056	0	0.4742	0.1768	0	0	0.8232	0	0.1086	0	0.1179	0	0.7736	0	0	0	1
12	0	0.1475	0.1966	0.6559	0	0	1	0	0	0	0	0	0	0.7319	0	0.2681	0.6306	0	0	0.3694
13	0	0.4659	0.4851	0	0	0.0489	0.7370	0	0	0.2630	0.1063	0	0.1187	0	0	0.7749	0	0	0	1
14	0.3470	0	0.6530	0	0	0	1	0	0	0	0.3470	0	0.6530	0	0	0	1	0	0	0
15	0	0.1742	0.1971	0.1402	0.1576	0.2190	1	0	0	0	0	0.1742	0.1971	0.1402	0.1576	0.2190	1	0	0	0
16	0	0	0	0.1233	0.6665	0.2102	0.9408	0.0592	0	0	0	0	0	0.1233	0.6665	0.2102	0.9408	0.0592	0	0
17	0.0714	0	0	0	0	0.6663	0	0.2626	0	0.7374	0.0714	0	0	0	0	0.6664	0	0.2626	0	0.7374
18	3.0677	0	7.2334	0	0	2.2682	1	0	0	0	3.0677	0	7.2334	0	0	2.2682	1	0	0	0
19	1	0	0	0	0	0	0	0.1262	0.1696	0.7042	1	0	0	0	0	0	0	0.1262	0.1696	0.7042
20	1	0	0	0	0	0	0.2565	0.7375	0	0.0060	1	0	0	0	0	0	0.2565	0.7375	0	0.0060
21	0	0	0	0	0	1	0.4175	0.5825	0	0	0	0.7500	0	0	0.1832	0.0668	0	0.5011	0.2130	0.2858
22	0.1306	0	0	0	0.3365	0.7957	0	0	0.0613	0.9387	0.1306	0	0	0	0.3365	0.7957	0	0	0.0613	0.9387
23	0	0	0	0.8066	0	0.1934	1	0	0	0	0	0	0	0.8066	0	0.1934	1	0	0	0
24	1	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	1	0	0	0

Table 2: The weight distribution of variables in AHP/DEA model (2^{1-9} and 9/9-9/1)

	2^{1-9}										9/9-9/1									
DMUs	Number of Employees	Number of Gates	Number of Runways	Size of Terminal Area	Length of Runway	Operational Expenditure	Number of Passengers	Amount of Freight and Mail	Aircraft Movement	Total Revenues	Number of Employees	Number of Gates	Number of Runways	Size of Terminal Area	Length of Runway	Operational Expenditure	Number of Passengers	Amount of Freight and Mail	Aircraft Movement	Total Revenues
1	0.1560	0.5449	0	0	0.2991	0	0	0.2459	0.7437	0.0104	0.1560	0.5449	0	0	0.2991	0	0	0.2459	0.7437	0.0104
2	0.4693	0	0	0.5307	0	0	1	0	0	0	0.4693	0	0	0.5307	0	0	1	0	0	0
3	0	0	0.2924	0	0	0	0	0.2932	0.7068	0	0	0	0.2924	0	0	0	0	0.2932	0.7068	0
4	0	1	0	0	0	0	0.7815	0	0	0.2185	0	0.2235	0	0	0.7141	0.0623	0.9677	0.0323	0	0
5	0.2729	0	0.2699	0.0090	0	0.4482	0	0	0.5514	0.4486	0	0.4156	0.5844	0	0	0	1	0	0	0
6	0.1909	0	0.8091	0	0	0	0.3647	0.1174	0.5179	0	0	0	0.8145	0.1855	0	0	1	0	0	0
7	0.3636	0	0.5807	0.0557	0	0	1.0000	0	0	0	0.4417	0.5583	0	0	0	0	1	0	0	0
8	0	0.1065	0.3621	0.0711	0.3129	0.1474	0	0	1	0	0	0.1065	0.3621	0.0711	0.3129	0.1474	0	0	1	0
9	0	0.3743	0.4029	0.0817	0.1411	0	1	0	0	0	0	0.3743	0.4029	0.0817	0.1411	0	1	0	0	0
10	0	0.1324	0.0934	0.2001	1.0823	0.7198	0	0	0	1	0	0.1324	0.0934	0.2001	1.0823	0.7198	0	0	0.0000	1
11	0	0.2747	0	0.3846	0	0.3407	0	0	0.0110	0.9890	0	0.3092	0	0.0758	0	0.6150	0	0	0.1422	0.8578
12	0.3615	0	0	0.6385	0	0	0.7353	0.2647	0	0	0.3615	0	0	0.6385	0	0	0.7353	0.2647	0	0
13	0	0.2887	0.0491	0.3218	0	0.3404	0.2468	0.1550	0	0.5982	0.3477	0	0.2253	0	0.0326	0.3944	0.3269	0	0	0.6731
14	0.1830	0	0.1536	0	0.6634	0	0	0	1	0	0.2725	0	0.7275	0	0	0	0.9283	0	0	0.0717
15	0	0.1742	0.1971	0.1402	0.1576	0.2190	1	0	0	0	0	0.1742	0.1971	0.1402	0.1576	0.2190	1	0	0	0
16	0	0	0	0.1233	0.6665	0.2102	0.9408	0.0592	0	0.0000	0.1267	0.6001	0.2732	0	0	0	1	0	0	0
17	0.0714	0	0	0	0	0.6664	0	0.2626	0	0.7374	0.0714	0	0	0	0	0.6664	0	0.2626	0	0.7374
18	3.0677	0	7.2334	0	0	2.2682	1	0	0	0	3.0677	0	7.2334	0	0	2.2682	1	0	0	0.0000
19	1	0	0	0	0	0	0	0.1262	0.1696	0.7042	1	0	0	0	0	0	0	0.1262	0.1696	0.7042
20	1	0	0	0	0	0	0.2565	0.7375	0	0.0060	1	0	0	0	0	0	0.2565	0.7375	0	0.0060
21	0	0	0	0	0	1	0.4175	0.5825	0	0	0	0	0	0	0	1	0.4175	0.5825	0	0
22	0.1306	0	0	0	0.3365	0.7957	0	0	0.0613	0.9387	0.1306	0	0	0	0.3365	0.7957	0	0	0.0613	0.9387
23	0	0	0	0.8066	0	0.1934	1	0	0	0	0	0.5550	0.3435	0.0931	0	0.0084	1	0	0	0
24	1	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	1	0	0	0

Table 3: The weight distribution of variables in AHP/DEA model (10/10-18/2 and ∅ mapping)

	10/10-18/2										∅ mapping									
DMUs	Number of Employees	Number of Gates	Number of Runways	Size of Terminal Area	Length of Runway	Operational Expenditure	Number of Passengers	Amount of Freight and Mail	Aircraft Movement	Total Revenues	Number of Employees	Number of Gates	Number of Runways	Size of Terminal Area	Length of Runway	Operational Expenditure	Number of Passengers	Amount of Freight and Mail	Aircraft Movement	Total Revenues
1	0.1560	0.5449	0	0	0.2991	0	0	0.2459	0.7437	0.0104	0.1560	0.5449	0	0	0.2991	0	0	0.2459	0.7437	0.0104
2	0.4693	0	0	0.5307	0	0	1	0	0	0	0.4693	0	0	0.5307	0	0	1	0	0	0
3	0	0	0.2924	0	0	0	0	0.2932	0.7068	0	0	0	0.2924	0	0	0	0	0.2932	0.7068	0
4	0	0.2237	0	0.7454	0	0.0309	0.3918	0.3410	0.2671	0	0.3089	0.6911	0	0	0	0	1	0	0	0
5	0	0.4156	0.5844	0	0	0	1	0	0	0	0	0.4156	0.5844	0	0	0	1	0	0	0
6	0	0	0.4574	0	0	0.5426	0.5739	0.0329	0	0.3932	0	0	0.8145	0.1855	0	0	1	0	0	0
7	0.3636	0	0.5807	0.0557	0	0	1	0	0	0	0.3636	0	0.5807	0.0557	0	0	1	0	0	0
8	0	0	0.4298	0.0617	0.3157	0.1928	0	0	1	0	0	0	0.3147	0.0868	0.3049	0.2936	0	0	1	0
9	0	0.5601	0	0	0.4399	0	1	0	0	0	0.2664	0	0.1031	0.0495	0.5809	0	1	0	0	0
10	0	0.1324	0.0934	0.2001	1.0823	0.7198	0	0	0	1	0	0.1324	0.0934	0.2001	1.0823	0.7198	0	0	0	1
11	0	0.0202	0	0.5056	0	0.4742	0.1768	0	0	0.8232	0	0.3092	0	0.0758	0	0.6150	0	0	0.1422	0.8578
12	0	0.1475	0.1966	0.6559	0	0	1	0	0	0	0.0175	0.0094	0	0.2921	0	0.6810	0	0.1055	0.1225	0.7719
13	0.0545	0	0.0347	0.5333	0	0.3776	0.1748	0.1950	0	0.6302	0	0.5471	0.3507	0.0579	0.0443	0	0.8229	0	0	0.1771
14	0.3470	0	0.6530	0	0	0	1	0	0	0	0.3470	0	0.6530	0	0	0	1	0	0	0
15	0	0.1742	0.1971	0.1402	0.1576	0.2190	1	0	0	0	0	0.1742	0.1971	0.1402	0.1576	0.2190	1	0	0	0
16	0	0	0	0.1233	0.6665	0.2102	0.9408	0.0592	0	0	0.1267	0.6001	0.2732	0	0	0	1	0	0	0
17	0.0714	0	0	0	0	0.6664	0	0.2626	0	0.7374	0.0714	0	0	0	0	0.6664	0	0.2626	0	0.7374
18	3.0677	0	7.2334	0	0	2.2682	1	0	0	0	3.0677	0	7.2334	0	0	2.2682	1	0	0	0
19	1	0	0	0	0	0	0	0.1262	0.1696	0.7042	1	0	0	0	0	0	0	0.1262	0.1696	0.7042
20	1	0	0	0	0	0	0.2565	0.7375	0	0.0060	1	0	0	0	0	0	0.2565	0.7375	0	0.0060
21	0	0.7500	0	0	0.1832	0.0668	0	0.5011	0.2130	0.2858	0	0.9284	0	0	0	0.0716	0	0.6008	0.1021	0.2971
22	0.1306	0	0	0	0.3365	0.7957	0	0	0.0613	0.9387	0.1306	0	0	0	0.3365	0.7957	0	0.0000	0.0613	0.9387
23	0	0	0.8203	0	0	0.1797	1	0	0	0	0	0	0	0.8066	0	0.1934	1	0	0	0
24	1	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	1	0	0	0

Appendix V: Upper and lower bounds of variables weight ratios: VS I

Table 1: e^{1-9} scale

Input Weight Ratio	Upper	Lower	Output Weight Ratio	Upper	Lower
WI1/WI2	3.4666	0.0246	*WO1/WO2*	8.7298	0.1889
WI1/WI3	4.4920	0.0187	*WO1/WO3*	20.0869	0.2636
WI1/WI4	3.5136	0.0235	*WO1/WO4*	15.7794	0.0233
WI1/WI5	3.4009	0.0419	*WO2/WO3*	20.869	0.1889
WI1/WI6	1.6280	0.0009	*WO2/WO4*	3.5209	0.0233
WI2/WI3	4.4721	0.1129	*WO3/WO4*	2.742	0.002
WI2/WI4	6.8199	0.2730			
WI2/WI5	12.3694	0.4699			
WI2/WI6	2.2217	0.0113			
WI3/WI4	15.0178	0.1547			
WI3/WI5	5.5249	0.3473			
WI3/WI6	4.6168	0.0087			
WI4/WI5	4.7428	0.2091			
WI4/WI6	3.4928	0.0093			
WI5/WI6	1.4852	0.0067			

Table 2: 2^{1-9}scale

Input Weight Ratio	Upper	Lower	Output Weight Ratio	Upper	Lower
WI1/WI2	0.0425	0.0112	*WO1/WO2*	20.1588	0.0992
WI1/WI3	0.0929	0.0245	*WO1/WO3*	65.3478	0.1574
WI1/WI4	0.1233	0.0123	*WO1/WO4*	56.1261	0.0076
WI1/WI5	0.2353	0.477	*WO2/WO3*	65.3478	0.0992
WI1/WI6	0.019	0.0004	*WO2/WO4*	8.2006	0.0076
WI2/WI3	4.167	0.459	*WO3/WO4*	6.0223	0.0002
WI2/WI4	14.5695	0.1532			
WI2/WI5	31.9222	0.3364			
WI2/WI6	4.7176	0.0033			
WI3/WI4	44.0653	0.0647			
WI3/WI5	11.0174	0.2346			
WI3/WI6	12.09	0.0022			
WI4/WI5	16.6049	0.1156			
WI4/WI6	9.735	0.0024			
WI5/WI6	2.6948	0.0017			

Table 3: 9/9-9/1scale

Input Weight Ratio	Upper	Lower	Output Weight Ratio	Upper	Lower
WI1/WI2	1.4133	0.2666	*WO1/WO2*	1.8418	0.6215
WI1/WI3	1.4722	0.2058	*WO1/WO3*	3	0.6933
WI1/WI4	1.3904	0.2779	*WO1/WO4*	1.5208	0.1304
WI1/WI5	1.383	0.3261	*WO2/WO3*	3	0.641
WI1/WI6	0.3686	0.0359	*WO2/WO4*	0.9212	0.1304
WI2/WI3	1.6836	0.5146	*WO3/WO4*	0.6216	0.0635
WI2/WI4	1.7987	0.6664			
WI2/WI5	2.2654	0.8051			
WI2/WI6	0.4627	0.0821			
WI3/WI4	2.7444	0.5265			
WI3/WI5	2.0256	0.7052			
WI3/WI6	0.6791	0.0788			
WI4/WI5	1.9665	0.6166			
WI4/WI6	0.5409	0.0835			
WI5/WI6	0.3797	0.0741			

Table 4: 10/10-18/2 scale

Input Weight Ratio	Upper	Lower	Output Weight Ratio	Upper	Lower
WI1/WI2	1.6649	0.184	*WO1/WO2*	2.4753	0.4966
WI1/WI3	1.8174	0.1564	*WO1/WO3*	4	0.5757
WI1/WI4	1.6609	0.1869	*WO1/WO4*	2.2533	0.1029
WI1/WI5	1.652	0.2346	*WO2/WO3*	4	0.5036
WI1/WI6	0.4857	0.0203	*WO2/WO4*	1.1548	0.1029
WI2/WI3	1.956	0.3948	*WO3/WO4*	0.8231	0.037
WI2/WI4	2.2793	0.5787			
WI2/WI5	3.0221	0.7336			
WI2/WI6	0.6322	0.0596			
WI3/WI4	3.404	0.4165			
WI3/WI5	2.2196	0.6218			
WI3/WI6	0.9389	0.0546			
WI4/WI5	2.5286	0.5049			
WI4/WI6	0.7828	0.0598			
WI5/WI6	0.4957	0.0491			

Table 5: ø mapping scale

Input Weight Ratio	Upper	Lower	Output Weight Ratio	Upper	Lower
WI1/WI2	1.3297	0.3737	*WO1/WO2*	1.6642	0.6744
WI1/WI3	1.391	0.3279	*WO1/WO3*	2.2361	0.7339
WI1/WI4	1.3251	0.3819	*WO1/WO4*	1.0423	0.1707
WI1/WI5	1.3224	0.4314	*WO2/WO3*	2.236	0.6813
WI1/WI6	0.3298	0.0554	*WO2/WO4*	0.7101	0.1707
WI2/WI3	0.14805	0.5928	*WO3/WO4*	0.556	0.0977
WI2/WI4	1.5958	0.7339			
WI2/WI5	1.8892	0.8414			
WI2/WI6	0.3981	0.101			
WI3/WI4	2.0644	0.6064			
WI3/WI5	1.6213	0.7609			
WI3/WI6	0.5127	0.0965			
WI4/WI5	1.711	0.6777			
WI4/WI6	0.4444	0.1013			
WI5/WI6	0.3448	0.0922			

Appendix VI: Upper and lower bounds of variables weight ratios: VS II

Table 1: e^{1-9} scale

Input weight ratio	Upper	Lower	Output Weight Ratio	Upper	Lower
WI1/WI2	3.7938	0.0216	*WO1/WO2*	8.7303	0.5134
WI1/WI3	3.2116	0.0256	*WO1/WO3*	20.0869	0.2636
WI2/WI3	14.3937	0.1353	*WO3/WO4*	20.0863	0.1889

Table 2: 2^{1-9}scale

Input weight ratio	Upper	Lower	Output Weight Ratio	Upper	Lower
WI1/WI2	6.3495	0.0049	*WO1/WO2*	20.159	0.3969
WI1/WI3	5.0396	0.0062	*WO1/WO3*	64.0072	0.1575
WI2/WI3	40.33	0.0625	*WO3/WO4*	64.0072	0.0992

Table 3: 9/9-9/1scale

Input weight ratio	Upper	Lower	Output Weight Ratio	Upper	Lower
WI1/WI2	1.4249	0.0098	*WO1/WO2*	1.8419	0.8502
WI1/WI3	1.3535	0.0062	*WO1/WO3*	3.0001	0.6934
WI2/WI3	2.6888	0.5095	*WO3/WO4*	3.0001	0.641

Table 4: 10/10-18/2 scale

Input weight ratio	Upper	Lower	Output Weight Ratio	Upper	Lower
WI1/WI2	0.1418	1.7296	*WO1/WO2*	2.4753	0.7642
WI1/WI3	0.1651	1.6107	*WO1/WO3*	4	0.5757
WI2/WI3	0.4099	3.2076	*WO3/WO4*	4	0.5036

Table 5: ø mapping scale

Input weight ratio	Upper	Lower	Output Weight Ratio	Upper	Lower
WI1/WI2	1.3585	0.2955	*WO1/WO2*	1.6643	0.861
WI1/WI3	1.305	0.3406	*WO1/WO3*	2.2361	0.7339
WI2/WI3	1.9645	0.5996	*WO3/WO4*	2.2361	0.6813

Appendix I: Research of Airport Performance Evaluation by DEA model

Authors	Method[1]	Sample	Indictors	
			Input	Output
Gillen and Lall 1997	DEA	21 US airports (1989–93)	Number of runways, gates, employees, collection belts, parking spots Length of runway Airport and terminal areas	Number of passengers Amount of cargos
Hooper and Hensher 1997	TFP model and Tornquist index	6 Australian airports (1988/89–91/92)	Labour, capital, and other cost	Non-aeronautical revenue Aeronautical revenue
Murillo-Melchor 1999	DEA and Malmquist	33 Spanish airports (1992–94)	Number of workers Accumulated capital stock proxied by amortization Intermediate expenses	Number of passengers
Parker 1999	DEA	32 UK regulated airports (1979/80–1995/96)	Number of labour Amounts of capital stock Non-labour and capital cost	Number of passengers Amount of cargo
Sarkis 2000a	DEA	44 US airports (1990–94)	Operational cost Number of employees, gates, runways	Number of passengers Aircraft movements Amounts of operational revenue Amount of cargo
Gillen and Lall 2001	DEA and Malmquist	22 US airports (1989–93)	Number of gates, runways, employees, collection belts, parking spots	Number of passengers Amount of cargo
Martin and Roman 2001	DEA	37 Spanish airports (1997)	Labour, capital, and materials cost	Number of aircraft movements Number of passengers Amount of cargo
Pels, ijkamp, and Rietveld 2001	DEA and SFA	34 European airports (1995–97)	Terminal size in square meters Number of aircraft parking positions at the terminal. check-in desks, collection belts, remote aircraft parking positions	(i) Terminal model: Number of passengers (ii) Movement model: Aircraft transport movement
Abbott and Wu 2002	Malmquist TFP index and DEA	12 Australian airports (1989/90–1999/2000)	Number of employees Amount of capital stock Length of runway	Number of passengers Amount of cargo
Fernandes and Pacheco 2002	DEA	35 Brazilian airports	Areas of apron Area of departure lounges, baggage claim Number of check-in desks, vehicle parking spots Length of curb frontage	Number of domestic passengers
Bazargan and Vasigh 2003	DEA	45 US airports (1996–2000)	Operational cost Non-operating expense Number of runways, gates, passengers, air carrier operations, other operations	Aeronautical revenue Non-aeronautical revenue Percentage of on time operations
Pacheco and Fernandes 2003	DEA	35 Brazilian airports (1998)	Areas of apron Area of departure lounges, baggage claim Number of check-in desks, vehicle parking spots Length of curb frontage	Number of passengers
Oum, Yu, and Fu 2003	TFP model, gross TFP, residual TFP	50 major airports around the world	Number of employees, runways, gates Terminal size	Number of passengers, aircraft movements Amount of cargo, non-aeronautical revenue

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[1] TFP=Total Factor Productivity; VFP= Variable Factor Productivity; DEA= Data Envelopment Analysis; SPF= Stochastic Production Frontier; FA=Stochastic Frontier Analysis

Authors	**Method**	**Sample**	**Indictors**	
			Input	**Output**
Pels, Nijkamp, and Rietveld 2003	SPA and DEA	34 Europeans airports (1995–97)	(i) Terminal model: Terminal size in square meters Number of aircraft parking positions at the terminal, remote aircraft parking positions, runways Dummy *z* variables for time restrictions and for slot-coordinated airport (ii) Movement model: Number of check-in desks	(i) Terminal model: Number of passengers (ii) Movement model: Aircraft transport movement
Barros and Sampaio 2004	DEA	Portuguese (1999–2000)	Number of labour Capital cost	Number of aircraft movements, passengers Amount of general cargo, mail cargo Non-aeronautical revenue Aeronautical revenue
Oum and Yu 2004	VEP	76 major airports around the world	Number of labour Soft cost input[2]	Number of passengers, aircraft movements Amount of non-aeronautical revenue
Sarkis and Talluri 2004	DEA	44 major US airports (1990–94)	Operational cost Number of employees, gates, runways	Number of passengers, aircraft movements Amount of operational revenue, cargo
Yoshida 2004	Endogenous-weight TFP	30 Japanese airports (2000)	Size of terminal Total length of runways	Aircraft movement Number of passengers, cargo
Yoshida and Fujimoto 2004	DEA and endogenous-weight TFP	67 Japanese airports (2000)	Length of runway Terminal size Access cost Number of employees	Number of passengers, aircraft movements Amount of cargo
Yu 2004	DEA	14 Taiwan airports (1994–2000)	Area of runway, apron, terminal Active route Population	Number of passengers, aircraft movements Aircraft noise
Lin and Hong 2006	DEA	20 major airports around the world (2003)	Number of employees, check-in desks, runways, parking spots, baggage claims, aprons, boarding gates Size of terminal area	Number of aircraft movements, passengers Amount of cargo
Martin and Roman 2006	DEA and SMOP	34 Spanish airports (1997)	Labor cost Capital cost Materials cost	Number of aircraft movements, of passengers Amount of general cargo, mail cargo Non-aeronautical revenue Aeronautical revenue
Oum, Adler, and Yu 2006	VEP	116 major airports around the world (2003–5)	Number of employees Soft cost input	Number of passengers, aircraft movements Amount of non-aeronautical revenue
Vasigh and Gorjidooz 2006	TFP model and regression model	22 US and European major airports (2000–2004)	Operation cost Net total assets Runway area	Operational revenue Non-operational revenue Total terminal passengers Total aircraft movements Landing fee
Barros and Dieke 2007	DEA	31 Italian airports (2001–3)	Labour costs Capital costs Operational costs excluding labour costs	Number of passengers, planes General cargo Handing receipt Non-aeronautical revenue Aeronautical revenue

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[2] Soft-cost input is a catch-all input other than labour and capital costs, including costs of outsourced services, consultant services, utility costs, travel expenses, non-labour building and equipment maintenance expenses, and repair costs.

Authors	Method	Sample	Indictors	
			Input	Output
Barros 2008a	DEA	32 Argentina airports (2003–6)	Number of labour, runways Area of aprons Terminal area	Number of passengers, aircraft movements Amount of general cargo
Barros 2008b	Random SFA model	27 UK airports (2000/1–2004/5)	Operational cost Price of workers Price of capital –premises	Price of capital-investment Number of passengers, aircraft movements
Barros and Dieke 2008	Two-stages DEA	31 Italian airports (2001–3)	Labor costs Capital costs Operational costs excluding labor costs	Number of passengers, aircraft movements General cargo Handing receipt Non-aeronautical revenue Aeronautical revenue
Fung, Wan, Hui, and Law 2008	DEA and Malmquist TFP index	25 Chinese airports (1995–2004)	Length of runway Terminal area	Number of passengers, aircraft movements Amount of cargo
Oum, Yan, and Yu 2008	SFA	109 world's airports (2007)	Number of labor, runways Non-labor variable cost Terminal size Wage rate Non-labor variable input price Labor cost share	Number of passengers, aircraft movements Non-aeronautical revenue
Pathomsiri, Haghani, Dresner, and Windle 2008	TFP and Malmquist-Lumberger index	56 US airports (2000–2003)	Land area Number of runways Size of runway area	(i) Desirable Number of passengers, Non-delayed flights Amount of cargo (ii) Undesirable Number of delayed flights Time delays
Yu, Hsu, Chang, and Lee 2008	DEA	4 Taiwan airports (1995–99)	Number of employees The accumulated capital stock Intermediate expense	Number of passengers
Barros 2009	Random SFA model	27 UK airports (2000–2006)	Operational cost Price of workers, capital – premises	Price of capital-investment Number of passengers, aircraft movements
Chi-Lok and Zhang 2009	DEA	25 China airports (1995–2006)	Terminal area Length of runway	Number of passengers, aircraft movements Amount of cargo
Lam, Low, and Tang 2009	DEA	11 major airports in Asia Pacific (2001–5)	Number of labor The value of capital Soft input Trade value	Air traffic movement (ATM) Number of passengers Amount of cargo.
Martin, Roman, and Voltes-Dorta 2009	Markov Chain Monte Carlo (MCMC) simulation and SFA model	37 Spanish airports (1991–97)	Number of labor Capital costs Material	Air traffic movement (ATM) Work-load units (WLU)
Ablanedo-Rosas and Gemoets 2010	DEA	37 Mexican airports (2009)	Number of operations per hour Number of passengers per hour	Air traffic movement (ATM) Number of passengers Amount of cargo
Assaf 2010	DEA and bootstrapped	27 UK airports (2007)	Number of FTE Size of airport area Number of runway	Air traffic movement (ATM) Number of passengers Amount of cargo
Tovar and Martin-Cejas 2010	SFA and Malmquist TFP index	26 Spanish airports (1993–99)	Number of labor, gates Airport area	Air traffic movement (ATM) Average size of aircraft Share of non-aeronautical revenues in total airport revenue
Yang 2010	DEA and SFA	12 Asia-Pacific airports (1998–2006)	Number of employees, runways Operational cost	Operational revenue

Authors	Method	Sample	Indictors Input	Indictors Output
Assaf 2011	Malmquist bootstrapped methodology	13 Australian (2002-2007)	No. of employees Size of terminal area Operational costs	Number of passengers, aircraft movements Amount of cargo
Barros 2011	SFA	17 Angola and Mozambique airports (2000-2010)	Operational cost Trend variables Price of workers, capital – premises	Price of capital-investment Number of passengers, aircraft movements
Curi, Gitto, and Mancuso 2011	Bootstrapped DEA	18 Italian airports (2000-2004)	Number of employees, runways Size of apron	Number of passengers, aircraft movements Amount of cargo
Fung, Chow 2011	Malmquist TFP index	41 Chinese airports (1995-2004)	Length of runway, size of terminal.	Number of passengers, aircraft movements Amount of cargo
Lozano and Gutierrez 2011	DEA	41 Spanish airports (2006)	Size of runway area, apron, terminal area Number of check-in desks, baggage claims, gates	Number of passengers, aircraft movements Amount of cargo
Tsekeris 2011	DEA	39 Greek airports (2007)	Operating hours Number of runways Size of terminal area Size of airplane parking area	Number of passengers Amount of cargo, Air traffic movement
Assaf and Gillen 2012	SFA And Bayesian model	73 world's airports (2002-2008)	Number of employees, runways, size of terminal, Other operational costs	Number of passengers, aircraft movements Non-aeronautical revenue
Assaf et al. 2012	Bayesian model	27 UK airports (1998-2008)	The price of labour, The price of capital, The price of materials	the total of aeronautical, non-aeronautical revenues
Chow and Fung 2012	TFP	30 airports in greater China (2000-2006)	Size of terminal, Length of runway	Number of passengers Amount of cargo, Air traffic movement
Gitto and Mancuso 2012a	DEA and bootstrapped technique	28 Italian airports (2000-2006)	Labour cost, capital invested, soft costs	Aeronautical revenue Non-aeronautical revenue
Gitto and Mancuso 2012b	TFP and bootstrapped technique	28 Italian airports (2000-2006)	Labour cost, capital invested, soft costs	Number of passengers Amount of cargo, Air traffic movement the total of aeronautical, non-aeronautical revenues
Perelman and Serebrisky 2012	DEA	21 Latin American airports (2000-2007)	Number of employees, runways, Size of terminal	Number of passengers Amount of cargo, Air traffic movement
Scotti et al. 2012	SFA	38 Italian airports (2005-2008)	Number of authorised flights per hours, number of aircraft parking positions, size of terminal, number of check-in desk, number of baggage claims, number of employees.	Number of passengers Amount of cargo, Air traffic movement
Wanke 2012a	Bootstrapped DEA and FDH	65 Brazilian airports (2009)	Air traffic movement	Number of passengers Amount of cargo,
Wanke 2012b	Bootstrapped DEA	63 Brazilian airports (2009)	Size of terminal, size of apron, number of runways, length of runway, number of aircraft parking positions, size of airport, number of parking space	Number of passengers Amount of cargo, Air traffic movement
Zhang et al. 2012	DEA	37 Chinese airports (2009)	Take-off distance available Landing distance available	Number of passengers Amount of cargo, Air traffic movement

Appendix II: Analytical Hierarchy Process (AHP) questionnaire

Airport Efficiency Evaluation Questionnaire

Dear Sirs/Madam,

I am currently undertaking a PhD research programme in Cardiff Business School, Cardiff University, examining airport efficiency in Europe and the Asia Pacific region using quantitative, analytical techniques. As part of this process, I am conducting a questionnaire survey which aims to rank airport efficiency indictors. It is expected that data collected through this questionnaire will help to develop an appropriate airport efficiency evaluation framework. As a senior manager in the airport industry, you are invited to provide your perceptions of airport efficiency. Your opinions are extremely crucial to this research; the attached questionnaire is part of the research. There are no right and wrong answers.

Your participation in this questionnaire survey is entirely voluntary. The information gathered in this survey will be treated in the **strictest confidence** and be used only for academic research purposes and you are entitled to withdraw your answer at anytime. This survey will take you about 10 minutes to complete. If you consent to participate in this survey, please fill out the questionnaire and send it back to us in the attached return envelope**.** If you have any queries or concerns regarding the survey, please contact either myself or my supervisor, Dr. Andrew Potter (PotterAT@cf.ac.uk). If you wish to receive a summary of the survey findings, please indicate this at the end of the questionnaire or e-mail us and I will be happy to send the summary to you when the research is over.

Please accept my thanks for your anticipated co-operation.

Yours faithfully,

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Questionnaire Explanation

In this questionnaire you will be asked to compare the following criteria which are used to evaluate airport operational efficiency. In this research, both variables can be separated into two hierarchies.

Input		
Main criteria	**Sub-criteria**	**Definition of the criteria**
Airport capacity factors	Number of employees	The number of full-time equivalent employees directly employed by the airport.
	Number of gates	The number of gates with jet ways and other non jet-way gates.
	Number of runways	The available number of runways at each airport.
	Size of terminal area	The total area of passenger terminals.
	Length of runway	The average runway length of every runway in each airport.
Financial factors	Operational cost	The financial resources needed to run an airport including salaries and benefits, communications and utilities, supplies, materials, repairs and maintenance, services and other expenses.
Output		
Main criteria	**Sub-criteria**	**Definition of the criteria**
Service performance	Number of passengers	The number of passengers arriving or departing at an airport (including terminal passengers and transit passengers).
	Amount of freight and mails	The weight of property carried on an aircraft and the weight of Post Office mail carried.
	Aircraft movement	The number of landings or take-offs of aircraft engaged in the transport of passengers, cargo or mail on commercial terms
Financial performance	Aeronautical revenues	The revenues that are generated by aviation activities such as landing fees, terminal fees, apron charges, fuel flowage, fixed base operators (FBOs), rentals and utilities.

How to complete the questionnaire

You are invited to tick the most appropriate box according to your opinion on how important one criterion over another when you are evaluating an airport operational efficiency. If your preference is between two levels of importance, e.g. between Strong Importance and Very Strong Importance, please tick the intermediate box between them.

Intensity of influence	Definition
EI	Equal Importance
MI	Moderate Importance for one over another
SI	Strong Importance
VSI	Very Strong Importance
ExI	Extreme Importance

Examples

Each row has a single comparison for you to make. As stated above, between two criteria "EI" means that both criteria are of Equal Importance. If you think, for example, the importance of *Numbers of Employees* over *Number of Gates* is Strong Importance, your answer should be placed on the left side subject to the degree of relative importance, and then you would tick as follows:

Criterion	Intensity of Importance																	Criterion
	ExI		VSI		SI		MI		EI		MI		SI		VSI		ExI	
Number of employees	☐	☐	☐	☐	√	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Number of gates

Tick √ means: the importance of *Number of Employees* over the criterion *Number of Gates* is a Strong Importance.

If, however, you think the importance of *Number of Gates* over the criterion *Number of Employees* is an Extreme Influence, then you should thick as follow:

Criterion	Intensity of Importance																	Criterion
	ExI		VSI		SI		MI		EI		MI		SI		VSI		ExI	
Number of employees	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	√	Number of gates

If the importance is the same, tick Equal Importance will be the answer.

Criterion	Intensity of Importance																	Criterion
	ExI		VSI		SI		MI		EI		MI		SI		VSI		ExI	
Number of employees	☐	☐	☐	☐	☐	☐	☐	☐	√	☐	☐	☐	☐	☐	☐	☐	☐	Number of gates

The Survey of Input variables

1. Comparison of main criteria

Criterion	Intensity of Importance																	Criterion
	ExI		VSI		SI		MI		EI		MI		SI		VSI		ExI	
Airport capacity factor	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Financial factor

2. Comparison of the relative importance of each sub-criterion in second hierarchy:
The Input variables: Airport capacity factors

Criterion	Intensity of Importance																	Criterion
	ExI		VSI		SI		MI		EI		MI		SI		VSI		ExI	
Number of employees	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Number of gates
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Number of runways
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Size of terminal area
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Length of runway
Number of gates	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Number of runways
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Size of terminal area
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Length of runway
Number of runways	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Size of terminal area
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Length of runway
Size of terminal area	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Length of runway

The Survey of Output variables

1. Comparison of main criteria

Criterion	Intensity of Importance																	Criterion
	ExI		VSI		SI		MI		EI		MI		SI		VSI		ExI	
Service performance	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Financial performance

2. Comparison of the relative importance of each sub-criterion in second hierarchy: The output variables: Service performance

Criterion	Intensity of Importance																	Criterion
	ExI		VSI		SI		MI		EI		MI		SI		VSI		ExI	
Number of passengers	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Amount of cargos and mails
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Aircraft movement
Amount of cargos and mails	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Aircraft movement

3. Personal information:
This information will be used to enable clusters to be formed from the responses.
However, individual responses will not be identifiable.

A. What is your position in your company (choose one):

☐ Vice president or above ☐ Manager / Assistant manager ☐ Director /Vice director
☐ Sales representative ☐ Clerk ☐ Other (please specify):_____

B. How long have you worked in airport related sector?_____ years

If you would like to receive a summary of the results of this research, please contact us by e-mail so that we can send the report to you.

Thanks for your patience and help