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Evaluation of Airport Operating Efficiencies Using Data Envelopment Analysis

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EVALUATION OF AIRPORT OPERATING EFFICIENCIES USING DATA ENVELOPMENT ANALYSIS

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ABSTRACT

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Airport congestion represents a serious obstacle to the future growth of the air transportation industry in the United States. Future development of new airports, and expansion of existing ones is required to meet the growing demands in domestic and commercial air travel. Globalization of economies and international travel has placed additional burdens on airports nationwide. This growth is requiring airports to operate at peak efficiencies. Economic growth of surrounding industries is dependent on the airport that services that geographical region. The variations in functions that airports offer, and therefore the differences in operations, do not lend themselves to traditional efficiency measures. Determining airport operating efficiencies by Data Envelopment Analysis (DEA) techniques may identify operational areas that require adjustments in order to operate efficiently. Airport rankings are determined yearly by the Federal Aviation Administration (FAA) based on the number of passenger enplanements made at each airport. From the FAA rankings, the top fifteen airports have been selected and their operating efficiencies determined. In addition, five regional airports were selected, and their operating efficiencies determined and compared to the top fifteen ranked airports. These comparisons established what airports operate efficiently, and what is required to make those inefficient airports efficient.

DEDICATION

The work contained within this thesis, is dedicated to my mother and father, Betty Maxine Cummings and Ewell Dixon Cummings. Without their support and dedication to my dreams and wishes, I could not have achieved the things that I set out to accomplish. Their guidance and beliefs have provided virtues and integrity that are to this day a focal point in my life. In addition, I want to thank my godparents, Pat and Willard Snyder, whom I have always looked up to. Throughout my years they too have provided unyielding support and encouragement. Last but far from least my son Kyle, who gives inspiration and purpose to so much in my life.

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NOMENCLATURE

SYMBOL	DEFINITION
ASCII	American Standard Code for Information Interchange
CRS	Constant Return To Scale
DMU	Decision Making Unit
DEA	Data Envelopment Analysis
EPS	IDEAS representation of (ε)
FAA	Federal Aviation Administration
RTS	Return To Scale
VRS	Variable Return To Scale
T	Rank sum being compared to rank limits
E	Standard Efficiency
BCC	Banker, Charnes, and Rhodes Model
CCR	Charnes, Cooper, and Rhodes Model
D_1	Relative frequency distribution for n_1
D_2	Relative frequency distribution for n_2
T_1	Rank sum of n_1
T_2	Rank sum of n_2
T_L	Rank sum critical value for lower limit
T_U	Rank sum critical value for upper limit
i	Index, $i = (1,\ldots,m)$
j	Index set, $j = (1,\ldots,n)$
k	Airport or DMU
m	Inputs
n	Number of iterations (DMUs)
r	Index, $r = (1,\ldots s)$
s	Outputs
x	A singular input
y	A singular output
z	Test statistic
n_1	Population sample size of major airports
n_2	Populations sample size of regional airports
n_p	Total population ($n_1 + n_2$)
s_i^-	Negative slack of i^{th} input

NOMENCLATURE (Continued)

SYMBOL	DEFINITION
s_r^+	Positive slack of r^{th} output
u_k	Unconstrained, projection adjustment of k^{th} DMU
u_r	Weight of r^{th} output
v_i	Weight of i^{th} input
x^s	Slack for a single input variable (m)
x'_i	Projected input for i^{th} input relative to (θ)
x_{ij}	i^{th} output of j^{th} DMU
x_{ik}	i^{th} output of k^{th} DMU
x_p	Reduction multiplier for p^{th} input
y'_i	Projected output for i^{th} output relative to (θ)
y_{rj}	r^{th} output of j^{th} DMU
y_{rk}	r^{th} output of k^{th} DMU
α	Shape parameter
β	y - coordinate adjustment (y x θ)
Δ	x - coordinate adjustment (x x θ)
ε	Non-archimedean (infinitesimal) constant
λ	Portion of an efficient DMU used in a reference set
λ_j	Portion of efficient DMU for j^{th} DMU being evaluated
μ_r	Output weight of r^{th} output (transformed)
ω	y - coordinate slack adjustment
σ_I	Projected input determined from (E)
τ	x-coordinate slack adjustment
θ	A Scalar proportional reduction of Inputs
ν_i	Input weight of i^{th} input (transformed)
*	Denotes the combination and removal of sub-variables

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CHAPTER I

INTRODUCTION

Traditionally, an organization provides a service or product by completing a series of tasks. An airport is a service organization. The number of customers who use the parking facilities, or have luggage handled, are examples of the services an airport provides. For a manufacturing organization, the number of holes drilled at one machine station before it proceeds onto the next station, is an example of the steps necessary to ultimately provide a finished product. Each service or manufacturing step is required to be performed efficiently in order for the service rendered, or manufactured item to be completed. Inherently, many organizations have numerous operations, so being able to determine if their operating process is efficient has become increasingly complicated.

Due to economic pressures and competition between organizations providing similar services, it is important to understand where improvements in operations can occur. Changes in organizational structure and operations are implemented in an attempt to improve organizational performance. Organizations of similar size, operations and attributes may be compared to each other using measures of central tendency. Under this approach, an organization may be compared to another using the mean, median and mode of a process common among them. Measures of central tendency provide insight into an organization's performance relative to an industry average, although it is difficult to determine specific areas that require improvement.

Another method of comparing organizations is the standard efficiency method. This method determines a standard output and input to a process. A standard input may be the combination of all operational expenses, and a standard output may be the gross revenues that operation produced. Traditional productivity measures require the combination of variables into a common unit such as cost or time (Anderson, 1997). Each organization's efficiency is calculated by dividing the output by the input to obtain a ratio. Efficiency ratios are determined for an organization as a whole, or for a specific process within the organization. The ratios of each organization are compared to each other to give a measure of performance. Although most airport operations are very similar to each other because of Federal Aviation Administration (FAA) regulations (FAA, DOT, 1997; NASA, 1975), variations in their size cause large variations in monetary resources.

Data Envelopment Analysis (DEA) is an extremely capable analysis tool. It can identify specific areas within an organization that require improvements, and the magnitude of adjustment needed to make them efficient (Charnes, Cooper, Lewin and Seiford, 1994). DEA's introduction is credited to work done by Charnes, Cooper and Rhodes (1978). DEA provides a method to compare airports against each other regardless of their physical, operational, or economic size (Cummings and Fernandez, 1997).

The Chicago Manual of Style, fourteenth edition was used as the journal model for this thesis

In addition, DEA does not require that the variables used in the modeling have identical units, therefore providing a more complete representation of the organizations being evaluated.

The purpose of this research is to determine operational efficiencies and strengths within a population of selected airports. Operational weaknesses have been determined, and areas that need improvements identified. The top fifteen ranked airports are chosen based on passenger enplanement rankings. In addition, five regional airports are selected to compare operational efficiencies against the larger airports. Various inputs and outputs were collected during the analysis process. The inputs and outputs collected represent airport operations. In DEA inputs are generally defined as those that consume resources such as cost or expenses, and outputs as those that generate resources such as profit or number of passenger enplanements. Consistency among inputs and outputs for each airport is required, this means that the same type of variables are defined across all the airports within the analysis. For example, if the number of passenger enplanements, or tons of cargo is used in determining one airport's efficiency, then these same variables need to be used in all the airports being evaluated. The same is true if a variable is removed from one airport, it therefore needs to be removed from all the airports under evaluation.

CONCEPTS OF DATA ENVELOPMENT ANALYSIS

DEA is a linear programming (LP) based technique for measuring relative efficiencies. Using traditional approaches to efficiency measures, multiple inputs and outputs for an organizational unit such as an airport, make comparisons between one unit and another difficult. In DEA each organizational unit is referred to as a Decision Making Unit (DMU). Various inputs and outputs can be used to determine a DMU's relative efficiency.

By collecting various outputs and inputs relative to an airport's operation, one can determine if the airport as a whole is efficient, or if a specific operational aspect is efficient. An example of a specific operational area would be airport operated parking facilities. Output variables for this example may be revenues generated by parking, and the number of cars leaving the parking facility. Examples of inputs that may be used, are the expense of maintaining the parking facility, number of employees to operate the facility, and hours of operation. These output and input variables can provide a relative operational efficiency measure of airport parking facilities for a population of airports.

A DEA model analyzes each DMU one at a time relative to all the other DMUs. As a result a single DMU or a number of DMUs may be determined to be efficient. Their efficiency is determined based on optimal utilization of outputs and inputs, as compared to each DMU independently. These efficient DMUs define what is known as an efficiency frontier. The efficiency frontier is a piecewise linear faceted boundary, that efficient DMUs lay upon, and therefore define its shape. The boundary defines an operational goal that each DMU must obtain in order to be efficient. Those DMUs that do not lay on the efficiency frontier are inefficient. The DEA model will determine what output or input reductions or increases are required to project the inefficient DMU unto the efficiency frontier. There are four basic DEA models: the Charnes, Cooper, and Rhodes (CCR) model (1978); Banker, Charnes, and Cooper (BCC) model (1984); the Additive model, and Multiplicative model. Each model is capable of addressing relative efficiencies for a population of organizations or processes. Return To Scale (RTS) is an attribute each model has and is the way an inefficient DMU is projected onto the efficiency frontier. Differences between the CCR and BCC models exist in the way they RTS, which is directly related to the shape of their envelopment surface, and metric. The CCR uses a Constant Return to Scale (CRS) and the BCC uses a Variable Return to Scale (VRS). The CCR model generates a conical hull (or cone) and is constrained more than the BCC model. The efficiency frontier for a BCC model is convex, and maps a frontier known as a convex hull that restricts the feasible region. Discussion on the differences between the CRS and VRS will follow in Chapter III. The Additive and Multiplicative models mentioned also provide efficiency frontiers, but are limited in the way they optimize efficiencies. Neither of these models use the non-archimedean variable (ε), the effects of this will be discussed in detail later in this Chapter. In addition there are hybrid modifications of these models that have been developed (Anderson and Uslu, 1997).

As discussed, the primary difference between the CCR and BCC models is their approach to RTS. The effects of the different RTS on the number of efficient DMUs will be demonstrated in Chapter IV. Both models allow optimization of inputs (x) or outputs (y). The CCR and BCC models are oriented relative to the desire to reduce input or output, or a combination of the two. An input oriented model determines the proportional reduction of all the inputs to maximize the defined output. The reverse is true for an output oriented model. The inputs are maintained and the output is optimized relative to all the DMUs in the formulation with an efficiency of one ($\theta = 1$). How each DMU evaluates itself against its peers is an important DEA strength (Andersen and Ushi, 1997).

Both the CCR model, and the BCC model have a primal and a dual formulation. The formulations that follow are for input oriented models. Output oriented model formulations are very similar, and can be found in Charnes, Cooper, Lewin, and Seiford (1994). The formulations for the Additive and Multiplicative models are available in Charnes, Cooper, Lewin, and Seiford, (1994).

The formulation of the Input oriented CCR primal model is :

$$\min_{\theta,\lambda} \theta \tag{1}$$

$$\text{s.t.} \quad \sum_{j=1}^{n} y_{rj}\,\lambda_j \geq y_{rk}$$

$$\sum_{j=1}^{n} x_{ij}\,\lambda_j \leq \theta\, x_{ik}$$

$$\lambda \geq 0$$

Equation (1) does not utilize (ε), or slack, and therefore the optimization of (θ) is done in a manner that the inputs are not being utilized properly (Andersen and Hollingsworth, 1997). The variable (λ) defines what portion of the efficient DMUs will be utilized to make an inefficient DMU efficient, this will be discussed in detail in Chapter IV. The constant (ε) in Equation (2) is defined as an infinitesimal constant that allows the minimization over (θ) to preempt the optimization involving the slacks. The variable (θ) is the proportional reduction applied to each DMU's input or output depending on the model being input or output oriented. The first stage focuses on the maximum reduction of inputs via the optimal (θ); then the second stage evaluates the movement onto the efficient frontier via the slack variables (s^+ and s^-) (Charnes, Cooper, Lewin and Seiford, 1994).

$$\min_{\theta, \lambda, s_r^+, s_i^-} \quad \theta - \sum_{r=1}^{s} \varepsilon s_r^+ - \sum_{i=1}^{m} \varepsilon s_i^- \tag{2}$$

$$\text{s.t.} \quad \sum_{j=1}^{n} y_{rj} \lambda_j - y_{rk} - s_r^+ = 0$$

$$\theta x_{ik} - \sum_{j=1}^{n} x_{ij} \lambda_j - s_i^- = 0$$

$$\lambda_j, s_r^+, s_i^- \geq 0$$

where :

θ	=	a scalar proportional reduction of inputs
s	=	outputs,
m	=	inputs,
s_r^+	=	positive slack for r^{th} output,
s_i^-	=	negative slack for i^{th} input,
n	=	number of iterations (DMUs),
x	=	a singular input,
y	=	a singular output,
k	=	DMU,
ε	=	non-archimedean (infinitesimal) constant,
i	=	index, $i = (1,\ldots,m)$,
j	=	index set, $j = (1,\ldots,n)$,
r	=	index, $r = (1,\ldots s)$,
y_{rj}	=	output variable of r^{th} output and j^{th} DMU,
y_{rk}	=	output variable of r^{th} output and k^{th} DMU,
x_{ik}	=	output variable of i^{th} output and k^{th} DMU,
x_{ij}	=	output variable of i^{th} output and j^{th} DMU,

λ_j	=	portion of efficient DMU for jth DMU being evaluated,
u_r	=	output weight of r^{th} output,
v_i	=	input weight of i^{th} input,
μ_r	=	output weight of r^{th} output (transformed),
ν_I	=	input weight of i^{th} input (transformed), and
u_k	=	unconstrained, dual variable for k^{th} DMU.

The formulation of the Input oriented CCR (dual) model is :

$$\max_{u,\,v} \frac{\sum_{r=1}^{s} u_r\, y_{rk}}{\sum_{i=1}^{m} v_i\, x_{ik}} \tag{3}$$

$$\text{s.t.} \quad \frac{\sum_{r=1}^{s} u_r\, y_{rj}}{\sum_{i=1}^{m} v_i\, x_{ij}} \leq 1$$

$$u_r \geq 0$$

$$v_i \geq 0$$

The formulation in Equation (3) is nonlinear and therefore does not lend itself to a LP. It is converted to a LP by maximizing the numerator (outputs) and constraining the denominator (inputs) to one. This approach is required to allow standard LP software to evaluate each DMU.

$$\max_{\mu,\nu} \sum_{r=1}^{s} \mu_r\, y_{rk} \tag{4}$$

$$\text{s.t.} \quad \sum_{i=1}^{m} \nu_i\, x_{ik} = 1$$

$$\sum_{r=1}^{s} \mu_r\, y_{rj} - \sum_{i=1}^{m} \nu_i\, x_{ij} \leq 0$$

$$\mu_r,\, \nu_i \geq \varepsilon$$

Equation (4) is the linear form of Equation (3). Maximizing the output for each DMU is the objective function for an input oriented model. No DMU will be more than 100 percent efficient ($\theta \leq 1$).

The transformation of (u) and (v) to (μ) and (ν) respectively, denotes the transformation from a non-linear to linear LP.

The formulation of the input oriented BCC primal model is :

$$\min_{\theta, \lambda, s_r^+, s_i^-} \quad \theta - \sum_{r=1}^{s} \varepsilon s_r^+ - \sum_{i=1}^{m} \varepsilon s_i^- \tag{5}$$

$$\text{s.t.} \quad \sum_{r=1}^{n} y_{rj} \lambda - y_{rk} - s_r^+ = 0$$

$$\theta x_{ik} - \sum_{i=1}^{n} x_{ij} \lambda_j - s_i^- = 0$$

$$\sum_{j=1}^{n} \lambda_j = 1 \text{ (Convexity constraint)}$$

$$\lambda_j, s_r^+, s_i^- \geq 0$$

The formulation of the Input oriented BCC (dual) model is :

$$\max_{\mu, \nu} \quad \sum_{r=1}^{s} \mu_r y_{rk} + \mu_k \tag{6}$$

$$\text{s.t.} \quad \sum_{i=1}^{m} \nu_i x_{ik} = 1$$

$$\sum_{r=1}^{s} \mu_r y_{rj} - \sum_{i=1}^{m} \nu_i x_{ij} + \mu_k \leq 0$$

$$\mu_r, \nu_i \geq \varepsilon$$

μ_k unconstrained

Equation (5) and (6) show the primal and dual formulations for the BCC model. The BCC model is very similar to the CCR model, the difference being the way the efficiency frontier is defined, and therefore the way that the inefficient DMUs are projected onto the efficiency frontier. The convexity constraint in the primal formulation, and the unconstrained dual variable (μ_k) in the dual formulation, provide an efficiency frontier that has convexity. Therefore, its piecewise linear shape falls closer to more DMUs. This may result in a higher percentage of efficient (θ=1) DMUs. Because of this, a DMU that may be border line efficient is harder to differentiate from the other efficient DMUs.

DEA is ideal for comparing the relative efficiencies of two or more organizations; particularly those with multiple inputs and outputs of different units of measure. There are associated weights for each input and output (μ, ν) respectively, sometimes refereed to as prices. Standard efficiency ratings are done by simple ratios between the output (y) and the input (x).

$$E = y/x \tag{7}$$

Standard efficiency ratings usually are done for organizations or processes that are very similar in size, whether the size be physical or functional. Equation (7) shows this approach requires that both the output (y) and input (x) have the same units. These units are quantitative and are required to be dimensionally identical. The units can be in dollars, pounds, hours, etc. Unlike DEA, this approach does not allow direct comparison of one DMU to another. At best, a general comparison of one efficiency to another is available. But when there are multiple outputs and inputs or both, we want to know which of those variables are driving the DMU to be inefficient. In standard efficiency measurements (E), each output and input has the same level of importance. An example follows:

Assume we have two output and four input variables respectively. In a standard efficiency analysis, the variables for each are aggregated to result in one output and one input respectively. This requires that all variables have the same units. This implies that the two outputs are of equal importance, making their weights 0.5 and 0.5 respectively. For the four variables that make up the input, their weights equate to 0.25, 0.25, 0.25, and 0.25 respectively. This weighting scheme does not allow any one variable to be more important than another, in reality their level of importance in determining an efficiency may be significantly different.

The use of DEA compares each airport to an efficient airport or to a set of efficient airports. There are fundamental assumptions that DEA uses. If a given airport, (A), is capable of producing y(A) units of output with x(A) units of input, then other airports should be able to do the same if they operate at the same level of efficiency. Similarly if an airport (B) is capable of producing u(B) units of output with v(B) units of input, then other airports should be capable of the same production.

The various models that are available in DEA may lead to different results. Orientations within the CCR and BCC model will also provide differences in the results. When selecting a model to use, the major choices are the way its envelopment surface is defined, and the RTS that the inefficient DMUs will take. The implementation of (ε) as an arbitrarily small number (10^{-6}) can cause numerical difficulties. The correct algorithmic implementation requires a two stage preemptive approach. This will be discussed further in Chapter IV. The choice of a particular DEA model determines :

- The implicit RTS properties,
- The geometry of envelopment surface, and
- The efficient projection that the inefficient DMUs take to the efficiency frontier.

PROBLEM BACKGROUND

Airports do not usually compete directly with each other due to their geographical separation. They provide a significant amount of economic strength and growth to businesses within their geographical region of operation (Howard, 1974; Taneja, 1988). They extend the economic boundaries by providing access to national and international cities, and therefore create new business opportunities. Operating efficiencies of airports are required to be at their peak to ensure maximum economic benefits. By using DEA to determine the operating efficiencies of the selected airports, their respective strengths and weaknesses are identified.

Airports are able to exist like any other business because of the revenue they generate. Although many are FAA subsidized, they are still required to operate financially efficient. When determining the required input and output variables, both must be related to the DMUs (Anderson and Hollingsworth, 1997). The variables used need to be representative of a DMUs operations, and be applicable to all the DMUs being analyzed. An example of a variable that is not related to an airport would be the number of cars sold at a neighboring car dealer to airport customers. Airports obtain their revenue through five major sources : landing area, terminal concession, airline leased areas, other leased areas, and other operating areas. Table 1.1 defines each of these sources.

Table 1.1
Airport Revenue Sources

Revenue Source	Description
Landing Area	Fees paid by airlines to land and operate aircraft and airline related functions.
Terminal Concession	Fees paid by concession vendors to operate within an airport facility. Percentages of sales can be a function as well.
Airline Leased Areas	Fees paid by airlines for use of baggage areas, ticketing and general passenger/airline support.
Other Leased Areas	Fees paid by vendors selling magazines and convenience items.
Other Operating Areas	Fees paid by support functions such as fuel, and catering.

These sources may be classified into two functional areas, operating and non-operating revenues (Dixon, 1980; Howard, 1974), and are classified as outputs for this DEA study. Operating sources are those directly related to airport operations, and non-operating sources are those that are non-airport activities. For a typical airport, on an average approximately ninety-six percent of revenues come from operating sources and the remaining four percent from non-operating (Howard, 1974). The number of actual passenger enplanements an airport provides effects these percentages. There is a relationship between enplanements and the revenues generated within an airport. Fees airlines must pay to operate in an airport, as well as vendor profits from passenger traffic within the airport generate these revenues. For a typical airport, variations in these revenues can vary plus or minus three percent for operating sources, and plus or minus four percent for non-operating (Howard, 1974).

Due to variations in operating responsibilities and differences in cost structure, operating expenses are not as clearly defined as the revenues generated. This is due to the services that an airport may or may not provide. An example of this is utility cost for environmental control systems. Climate differences among airports, can cause wide variations in the system operating cost. Airport staffing vary widely from airport to airport also impacting operational expenses. In general, airport operational expenses are divided into two categories, maintenance and operating (Howard, 1974). Maintenance expenses are those that an airport has to perform to ensure the airport and airport related facilities are operating safely and functionally correct. An example of this would be the cleaning and replacement of worn equipment. Non-operating expenses can be divided like operating expenses as well. Examples of the latter is interest on bonds or loans. For a typical airport, approximately ninety-one percent of the expenses are associated with operating sources and nine percent from non-operating sources. Variations as much as plus or minus four percent in both types of sources can occur depending of number of passenger enplanements (Howard, 1974).

Understanding the economic impact that an airport has on the geographical region it services is important. Insight to economic factors may assist the geographical region in resolving any economic deficiencies. There is a direct correlation between an airport's operating efficiency and the performance of the regional economy (Economic Benefits, 1997). The benefits that an airport provides to its regional economy and to the national economy may be defined by three impact components: direct, indirect and induced (Economic Benefits, 1997; Landrum and Brown, 1995). These components and the factors they influence can be seen in Figure 1.1. The economic benefit of air transport is assessed by looking at the full extent of the industry's impact on the global economy; from the actual movement of passengers and freight, to the stimulation of economic growth.

Direct economic impacts are found by measuring the monetary activities of airlines, airports, and businesses located at airports. The latter includes everything from fuel suppliers to vendors. Estimated values for the direct multiplier have ranged from 0.4 to 2.4, and can be seen in Table 1.3 (Economic Benefits, 1997). The indirect economic impact is derived from the off-airport activities of passengers and shippers, such as expenditures at travel agencies, hotels and restaurants, and tourist attractions. The induced impact represents the successive rounds of spending generated by all of the recipients of the direct and indirect economic benefits. For example, airline employees spend part of their salaries on new cars, auto dealer employees spend part of their salaries on groceries and so on. Airports and airlines make up the aviation industry. Airlines and airports are interdependent, and generate revenue, employment, and taxes (Economic Benefits, 1997). How these are related to each other is shown in Figure 1.1. Tables 1.2 and 1.3 show air transport economic impact and employment for 1994.

Airports act as a catalyst for economic growth. For example, an airport is a key part of the community, drawing millions of dollars into the economy by providing air transport services to tourists from outside, visitors from other regions, and international cargo carriers (Economic Benefits, 1997). Airports are the chief asset of regions wishing to attract new industries. Their presence offers strong inducement to companies to set up in a particular locale. A region cannot be marketed as a center for establishing major new businesses without an efficient air transport infrastructure, nor will it attract major investment (Economic Benefits, 1997).

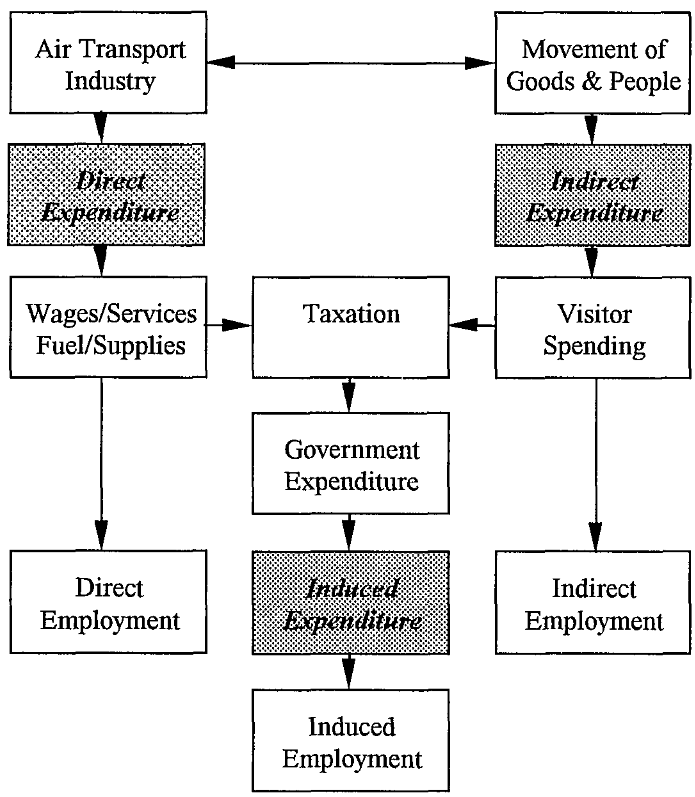

Figure 1.1. Components of Total Economic Impact

Table 1.2
Air Transport's Impact on World Economic Activity and Employment (1994)

Economic Components	Economic Activity (billion $)	Employment (million/jobs)
Direct	290	3.3
Indirect	300	7.4
Induced	550	13.3
Totals	1140	24

The high, medium and low estimates in Table 1.3, reflect the mix of international/national traffic (Economic Benefits, 1997); the assessment method used, consideration of regional versus national effects, and the importance of hubbing. The economic catalyst that airports have results from :

- Providing a mechanism for distributing goods and services worldwide,
- Contributing to industry growth,
- Increasing overall economic efficiency,
- Spawning new industries,
- Supporting of manufacturing practices (just in time),
- Fostering regional expansion of companies, and the
- Adding of international business opportunities.

Table 1.3
Typical Economic Impacts of Airports (Per 1 million Passengers)

Estimate	Jobs (Direct/Total)	Economic Impact (Millions $) (Direct/Total)
High	2000/8000	225/1600
Medium	1500/6000	75/650
Low	750/2500	35/130

Airports are an integral part of the economy. For this reason, airports have to operate efficiently. Efficient airports provide substantial economic growth and stability to the geographic region they service. Billions of revenue dollars and expenditures are generated each year through airport operations. If an airport is not operating efficiently, then the potential benefits to the economy as a whole are not fully realized. Operational efficiencies effect the airport as well. High efficiencies allow the airport to grow and change as required. Inefficient airports can find themselves in financial trouble, which can slowly degrade their operational abilities and functionality. This in turn not only affects the airport's ability to operate efficiently, but degrades the air transport system. The challenge with determining efficiency ratings for an airport or any similar organization, is how to take into consideration all the various factors that influence their efficiency.

PROBLEM STATEMENT

Conventional methods for estimating efficiency do not fully evaluate the organization as a unit, but from a segmented approach. Airports have a wide variety of operations that are conducted both on and off the airport site. By using standard efficiency measures, one can not differentiate between operational areas that may require improvements, or learn from those areas that are operating efficiently. Being able to define the outputs and inputs into separate variables, allows the identification of operational areas needing to be changed. DEA can provide insight to what operational area is likely in need of improvement, where standard efficiency measures can not. Additionally DEA can tell us what portion of an efficient DMU should be used as a reference to make an inefficient DMU efficient.

In the case of airports and many other organizations, it is important to look at all the variables that influence operational effectiveness. By doing this, one normally obtains a variety of variable units that represent a specific organization or process. With airports, there are numerous variables that are encountered depending on the interested operational efficiency. This thesis focuses on the operational efficiencies of airports. As a result several variables are introduced and have to be filtered out to best represent the operational aspects of an airport. DEA looks at organizations or processes that have similar functions, and compares each DMU against all DMUs within the model. Although we are looking at an organizational efficiency, DEA can be used for technical or design processes as well.

Airports in this study are selected based on FAA enplanement rankings. The FAA ranks airports yearly based on the number of passenger enplanements that are made at an airport. Table 1.4 provides the list of airports selected, and shows their corresponding enplanement rankings. The enplanement ranking data is readily available and can be obtained directly from the FAA as well as other aviation related organizations.

The top fifteen airports represent the major airports within the continental United States. In addition to the fifteen major airports chosen, a selection of five regional airports represent the airports within the mid-Atlantic region. These additional five will have their operational efficiency evaluated against the major airports, to see what influence each may have on the efficiency ratings. It is important to understand that the number of enplanements for commercial airport operations is directly related to airport revenues and therefore economic influences for the region they service. For every airport customer, the airport benefits by revenues produced. Airlines that operate out of an airport pay fees for the use of the airport, such as those listed in Table 1.1. Without passengers, airlines would not exist, and airports would not benefit from the revenue the airlines produce. There are also airport customers that provide revenue by buying concession items or vendor merchandise.

Table 1.4
(DMU) Airport Ranking and Selection (1995)

RANK	ID	AIRPORT NAME	ASSOCIATED CITY	ENPLANEMENTS IN 1995
1	ORD	CHICAGO O'HARE INTL	CHICAGO	31,433,002
2	ATL	THE WILLIAM B HARTSFIELD	ATLANTA	28,090,978
3	DFW	DALLAS/FORT WORTH	DALLAS-FORT	26,962,940
4	LAX	LOS ANGELES INTL	LOS ANGELES	26,133,795
5	SFO	SAN FRANCISCO INTL	SAN FRANCISCO	17,187,766
6	MIA	MIAMI INTL	MIAMI	16,065,673
7	DEN	DENVER INTL	DENVER	14,858,763
8	JFK	JOHN F KENNEDY INTL	NEW YORK	14,601,827
9	DTW	DETROIT METROPOLITAN	DETROIT	14,082,598
10	PHX	PHOENIX SKY HARBOR INTL	PHOENIX	13,738,433
11	LAS	MC CARRAN INTL	LAS VEGAS	13,243,748
12	EWR	NEWARK INTL	NEWARK	13,230,961
13	STL	LAMBERT-ST LOUIS INTL	ST LOUIS	12,790,701
14	MSP	MINNEAPOLIS-ST.PAUL	MINNEAPOLIS	12,559,491
15	BOS	GENERAL EDWARD LAWRENCE	BOSTON	11,734,693
50	RDU	RALEIGH-DURHAM INTL	RALEIGH/DURHAM	2,938,831
73	ORF	NORFOLK INTL	NORFOLK	1,335,378
82	RIC	RICHMOND INTERNATIONAL	RICHMOND	1,066,411
134	ROA	ROANOKE	ROANOKE	323,145
168	PHF	NEWPORT	NEWPORT NEWS	181,971

MODEL CRITERIA

During DEA modeling, consideration is given to all variables that effect airport operations. Data has to be directly related to the DMUs in question. Data variables that are not related to airport operations, can result in ineffective use of DEA and therefore inaccurate results. When selecting airport operation output and input variables, a general classification of each can be used as follows. Outputs are considered to be good, such as revenue generation, and inputs are considered bad such as expenses (Andersen, 1997). Discussion on data variables is provided in Chapter III.

Obtaining data values that have similar numeric ranges is desirable in DEA. Wide ranges of values can cause computational difficulties. These difficulties arise from ill conditioned data matrices (Charnes, Cooper, Lewin, and Seiford, 1994). Scaling of the data can be accomplished to balance a wide range of variable values, but this too can cause problems. An example of this would be having one variable in billions of dollars and another in tens of dollars. The problem can arise when the scaling of lower ordered digits occurs. This can destroy the ability to accurately discriminate between different units (Charnes, Cooper, Lewin, and Seiford, 1994).

In LP, when at least one of the basic variables has a value of zero, the linear program is said to be degenerate (Eppen, Gould, and Schmidt, 1993). DEA models are prone to this degeneracy. For an input oriented model, only the variables (θ) and (λ) have non zero values. All other basic variables have a value of zero making the basis degenerate (Charnes, Cooper, Lewin and Seiford, 1994). This can result in a significant amount of computational effort before an optimal solution is achieved. Cycling occurs every time no improvement in the value of the objective function occurs. There are methods to reduce this cycling effect. A general rule is to keep the total number of the outputs and inputs to less than or equal to ten (Charnes, Cooper, Lewin and Seiford, 1994).

$$\Sigma y + \Sigma x \leq 10 \tag{8}$$

Although cycling can still be noticeable when Equation (8) is not met, the degeneracy becomes worse as this value exceeds this condition. This is due to basic solutions having a high number of variables equal to zero. Detailed discussion of these conditions are covered in Chapter IV. Choosing the right model formulation, and following basic rules for data selection will ensure reliable DEA results.

APPLICATION OF DATA ENVELOPMENT ANALYSIS

Airports provide economic growth to the region they serve. The close relationships between direct, indirect, and induced expenditures associated with airports, show how the economy benefits. Both manufacturing and service organizations depend on airports to assist them in their daily operations. Airports provide a mechanism for distribution of goods, industry growth, and expansion into national and international markets. Airports that operate inefficiently are not providing maximum economic benefit. Determining if an airport is operating efficiently is not an easy task due to its operational complexity. The variety of outputs and inputs that are required to define an airports operation makes it well suited for DEA applications. With the use of multiple outputs and inputs in a DEA model, operational areas of an airport potentially causing the inefficiency are identified.

Determining those variables that give the best differentiation between airports, can impact the DEA outcome. Variable selection must be done prudently. It may be necessary to alleviate or add additional variables to obtain the best differentiation between the selected DMUs. One must choose the best DEA model to represent an organizations structure or process. The RTS and model orientation, need to fully define the organization or process. Employing basic rules for DEA modeling will ensure that the results are reliable. As with any analysis, the results are only as good as the data products used.

CHAPTER II

LITERATURE REVIEW

DEA was introduced in 1978, and since then hundreds of papers have been published regarding its use and development (Seiford, 1996). DEA has been used to measure efficiencies of various educational institutions, production processes, productivity techniques, utility services, and economic operations to name only a few. A comprehensive listing of applications is provided by Seiford (1996).

PRIOR WORK ON AIRPORT EFFICIENCY

To date, no research on the use of DEA to measure the relative efficiency of airports has been published. Utilization of DEA to determine the efficiency of various airlines was done, but not directly related to airport operations (Banker and Johnston, 1994). Currently the efficiency of airports is done with standard efficiency approaches, with general accounting practices used to monitor monetary performance. Neither the standard efficiency measure nor the general accounting practice is capable of identifying specific operational areas that require improvement. In an effort for the FAA to inform Congress on the financial performance of federally assisted airports, a notice was issued to all federally assisted airports on the requirement to file financial reports (Kurland, 1997). These reports will be used to monitor financial aspects of each federally assisted airport, and give a general measure of their monetary efficiencies. The FAA has a policy regarding rates and charges, and tries to ensure consistency with respect to an airport's operational abilities (Kurland, 1997), adjustments to these rates may be affected by the airports financial performance and need.

DATA ENVELOPMENT ANALYSIS WORK

The use of DEA began with Edwardo Rhodes during his Ph.D. research at Carnegie Mellon University (Charnes, Cooper, Lewin and Seiford, 1994). Mr. Rhodes compared the performance of school districts that were matched sets. The performance measures used were outputs such as increased self esteem, and inputs such as time spent by a mother reading to her child. This study was an attempt to compare the relative technical efficiencies of the schools, and developed into the use of multiple outputs and inputs. The use of multiple outputs and inputs initiated the formulation of the CCR ratio form of DEA. This formulation of the CCR ratio was first presented by Charnes, Cooper, and Rhodes, (1978), and later converted to a multiple output, multiple input by constructing a single "virtual" output to a single "virtual" input (Charnes, Cooper, Lewin and Seiford, 1994).

Between 1978 and 1995, there have been over seven hundred papers written directly related or relative to DEA (Seiford, 1996). Seiford provides a DEA family tree that shows the evolution of DEA through 1995. In the early 1980's DEA was restricted to the use of the CCR formulation, which provided a CRS. Computations during this period were crude, and the value of the non-archimedean variable (ε) was naively estimated to be 10^{-6} (Seiford, 1996). By the mid 1980's DEA had advanced further; the additive, multiplicative and BCC DEA model formulations were now available. These new models provided an additional RTS known as the VRS. The use of DEA in production applications grew and by the 1990's computer codes for all DEA models have been refined and are becoming readily available. The use of (ε) has also been successfully folded into DEA computer codes. A chronological order (as papers were presented or developments occurred) of key events follows, and is credited to (Seiford, 1996).

DATA ENVELOPMENT ANALYSIS HISTORY

Before DEA was developed in 1978, the foundation for its existence had to be created. Works by Afriat, (1972; Aigner and Chu , (1968; Sheperd, (1970; Debreu, (1951; Farrel, (1957; Koopmans ,(1951; and Pareto, (1927) provided ground work in the area of efficiency estimations. In 1962, Charnes and Cooper provided a linear fractional transformation. All these works were key in paving the way for DEA. As discussed in this chapter, Rhodes' dissertation led to the development of DEA. DEA methodology and approach was first published by Charnes, Cooper, and Rhodes (1978).

In the early 1980's, DEA was very simple as compared to today's models. Models then were limited to the single CRS which only measured technical efficiencies. Few applications of this approach were implemented, primarily in the education field, (Bessent and Bessent, 1980; Banker, 1980; Charnes and Cooper, 1980; Charnes, Cooper, and Rhodes, 1980; and Schinnar, 1980). DEA computation was extremely primitive during this time.

By the mid 1980's DEA was becoming more advanced. The CRS model was now joined with the VRS model. In addition the Multiplicative and Additive models were developed. A connection between production theory was established, with primary focus on relative efficiencies. Applications to hospitals Bedard, (1985; Nunmaker, (1983; and Sherman, (1981) are examples of DEA's growth. Post office operations, banking, mass transit, courts, maintenance, pharmacies, military applications are additional examples where DEA provided insight to operating efficiencies (Seiford, 1996).

By 1990 significant advancements were made in DEA regarding models, extensions, computational refinements, and practice. Studies comparing the various DEA models Ahn, (1988; Charnes, (1990; Epstein, (1989; and Seiford, (1990) provided a framework to understanding implicit assumptions and requirements. Extensions of models to utilize non-discretionary and categorical variables were introduced (Banker and Morey, 1986). Earlier misunderstandings over (ε) have been resolved, and computational issues addressed and implemented (Ali, 1990). Publications addressed more complicated issues such as taxes, software development, energy use, and logistics systems.

Theoretical advances of DEA, and its growth in practical applications, will continue to evolve. DEA has moved into the main stream of research and technology, and has become accepted as evidence by inclusion (Andersen, Sweeney, and Williams, 1991) in operations research textbooks. Studies using DEA have appeared in major publications such as Fortune magazine (Norton, 1994). Future research and development will focus on stochastic DEA models (Banker ,1993; Simar ,1992; Land ,1993; and

Olesen and Petersen, 1995). Lovell states, "until a stochastic DEA is developed, statisticians and econometricians will remain skeptical of the managerial and policy implications drawn from DEA (Lovell, 1994)".

APPLICABILITY OF DATA ENVELOPMENT ANALYSIS

DEA has come a long way since its initial introduction in 1978. It is used widely by researchers and practitioners in management sciences, and is accepted as a reliable tool to identify processes in need of improvements (Charnes, Cooper, Lewin and Seiford, 1994). The ability of DEA to effectively handle multidimensional outputs and inputs allows pertinent characteristics of an organization to be included in the evaluation process. The organization as a whole or a process of interest is represented accurately. Several applications of DEA regarding organizations with similar attributes, such as an airport, have been performed (Seiford, 1996). Implementation of recommended changes identified by a DEA approach have been accomplished. As a result operational efficiencies have increased (Norton, 1994).

The use of DEA in determining airport operating efficiencies is theoretically sound. Airports are complex organizations that are made up of several processes. DEA is capable of looking at an organization such as an airport as a whole, or at a specific process within the organization. Airports have numerous variables that effect their ability to operate efficiently, and many of the variables are interdependent. When evaluating an organization such as an airport, all the variables that define the organization or process need to be considered. The need for multiple outputs and inputs in order to mimic the organization or process being evaluated is required. Standard efficiency techniques are not adequate in determining specific operational areas that may require alterations.

CHAPTER III

APPROACH

The work done during this thesis falls into eight stages. Stages one and two were addressed in prior chapters. Stages three, four, and five are addressed in this chapter, stage six in Chapter IV, and finally stages seven and eight in Chapter V. The eight stages are :

1. Problem identification and understanding,
2. DEA understanding and maturity,
3. Model differences and selection,
4. Data definition and selection,
5. Model formulation,
6. Analysis,
7. Results and conclusions, and
8. Recommendations and actions

A brief recap of the problem provides insight to the direction taken. As discussed in Chapter I, inefficient airports can directly influence the economic stability of the region they serve. Air transportation is one of the fastest growing sectors of the world economy, and by the year 2010, could exceed eighteen-hundred billion dollars and thirty-three million jobs (ATAG, 1997). Knowing how the economy depends on airports, and the problems an inefficient airport can cause, it was decided to determine which of the airports identified in Table 1.3 are efficient, and what operational differences exist between the airports. The fifteen major airports identified in Table 1.3 are a small sample of the airports within the continental United States.

Identifying the DEA modeling approach to implement is crucial to providing reliable results. Different DEA models may provide different results. The basic choices are the envelopment surface, and the method of projection the inefficient DMUs take to reach the efficiency frontier. The way in which a model RTS can be a large factor in defining the number of efficient DMUs. The CCR model utilizes a CRS, and the BCC uses a VRS. Both the CRS and the VRS refer to the way the efficiency frontier is mapped. When defining the best efficiency frontier to use, first one must define, collect and select the data variables relative to airport operations. If the data provides a linear or another trend we can then narrow down which model or models are best suited. The basic assumption when using the CCR model is that you can double your output by doubling your inputs (Anderson, 1997). An example of this would be doubling the number of parts used to produce a product, which will in turn double the number of products produced. Using the CRS approach tends to lower the efficiency ratings, while the VRS tends to raise them.

Using an orientation approach, meaning focusing on proportionately reducing the output or input, narrows the model selection down to two: the CCR and the BCC. In this case it was decided early that current output levels would be maintained, and proportionately reduce the inputs. Output levels were maintained because FAA rankings of airports by passenger enplanements are fairly consistent. The fifteen airports being used have consistently been close to the rankings shown in Table 1.3. The correlation between number of passenger enplanements and revenues produced was discussed previously. Since this correlation exist, and FAA rankings of passenger enplanements is somewhat consistent, then it is assumed that revenue variations from year to year for the airports within this study are proportionate. Maximizing profit is always a goal for any organization. Therefore for the two reasons stated above, expenses will try to be optimized. When using the CCR model, the number of efficient DMUs found will also be found with the BCC model; although the reverse is not true. It was determined to run the analysis using both models and compare results, but with primary focus on the CCR modeling.

DATA SELECTION

After selecting the airports to be studied by the criteria discussed earlier, looking for reliable and appropriate data products on the airports is necessary. Several publications and data bases exist that have a variety of applicable data products (FAA DOT/TSC, 1997; FAA, 1995; United States Department of Transportation, 1996). The focus is on operational efficiency. Data on tons of cargo moved, number of enplanements, and similar attributes are readily available, but finding financial data was a challenge. Going directly to each airport and asking for financial data was not efficient or very reliable, and consistently obtaining data from each airport was unlikely. In March of 1997, the FAA implemented a new policy that solved this potential problem (Kurland, 1997). Any airport that fell under the fiscal year 1994 FAA authorization act, is now required to file a financial report. This act requires airports to file standard forms within one hundred and twenty days after an airport's fiscal year ends. The FAA was contacted, and the research to be done on airport efficiencies explained. A request for the financial data on the airports shown in Table 1.3 was submitted, and computer data files on all but those shown in Table 3.1 where obtained. The financial reporting forms are shown in Appendices A and B. Appendix C provides summations of specific variables found in Appendix B.

Table 3.1
Missing Airport Data

RANK	LOC	AIRPORT NAME	ASSOCIATED CITY	ST
1	ORD	CHICAGO O'HARE INTL	CHICAGO	IL
3	DFW	DALLAS/FORT WORTH	DALLAS-FORT	TX
9	DTW	DETROIT METROPOLITAN	DETROIT	MI
168	PHF	NEWPORT NEWS/WILLIAMSBURG	NEWPORT NEWS	VA

At the time the data was requested from the FAA, those airports listed in Table 3.1 had not submitted the required financial forms. This missing data brought the total airports to be analyzed by

DEA techniques to sixteen. A general rule is that the number of DMUs should be approximately three times the total number of the outputs and inputs (Anderson and Hollingsworth, 1997). With sixteen DMUs analyzed this requires the summation of outputs and inputs to be approximately five or six. Tables 3.2 and 3.3 show all the data products that were collected. At this point it is important to remember that an output and input should be quantifiable and related to their respective DMU. Another general rule is that the product of outputs and inputs is approximately equal to the number of efficient DMUs that will be found (Charnes, Cooper, Lewin, and Seiford, 1994). For example if we have three outputs and four inputs, then twelve efficient DMUs would be expected to be found. If there are only sixteen DMUs being evaluated then there is not much differentiation in the DEA model. Without differentiation, determining actual inefficient DMUs may not be achievable.

There are two basic data types in DEA, discretionary and non-discretionary. Discretionary data is data that is controlled, and non-discretionary is uncontrollable. Examples of discretionary data are outputs (y_{10} and y_{20}), and non-discretionary being the outputs (y_{30} and y_{40}) as defined in Table 3.2. The output and input variables were grouped to give a total of five outputs and four inputs. Tables 3.4 and 3.5 show the groupings used. The grouping was made following the basic modeling construction techniques that reduce the possibility of degeneration. This is not to imply that modeling was done with this many outputs and inputs, for this would disregard the general rule regarding the product of the outputs and inputs just stated. Chapter IV will explain how different combinations of output and inputs can be selected for a model of interest. The variables that were summed together were done so in a way that they were directly related to each other. The groupings follow the FAA guidelines provided in the financial reporting form (FAA DOT/TSC CY1995, 1997); (Kurland, 1997). The outputs and inputs are consistent for all the airports of interest.

The overall operational efficiency of the selected airports will be determined in this analysis. The outputs and inputs define an airport's overall operation. These variables fall under direct and indirect operational constraints and follow the guidelines shown in Figure 1.1. Many times the indirect output variables are not totally controllable by an airport, such as rental cars or off site parking. Airports indirectly effect these operations by the number of passengers deplaned and requiring these types of services. The inputs are also directly and indirectly controllable by an airport. This combination of direct and indirect variables further illustrates the connection between airport operations and the economy.

Table 3.2
Candidate Output Data (sub variables)

OUTPUT (y_n)	DESCRIPTION (Line item)	UNITS
y_{10}	Landing Fees	$
y_{11}	Terminal/International arrival area rental or other charges	$
y_{12}	Apron charges/tiedowns	$
y_{13}	Fuel flowage fees	$
y_{14}	Utilities	$
y_{15}	Fixed based operation (FBO) revenue: contract or sponsor-operated	$
y_{16}	Cargo and hanger rentals	$
y_{17}	Securities reimbursement	$
y_{18}	Miscellaneous	$
y_{19}	Other	$
y_{20}	Rent/land rental	$
y_{21}	Concessions	$
y_{22}	Parking	$
y_{23}	Rental cars	$
y_{24}	In-flight catering	$
y_{25}	Interest income	$
y_{26}	Royalties from natural resource sales	$
y_{27}	Miscellaneous	$
y_{28}	Other	$
y_{30}	Bond proceeds	$
y_{31}	Proceeds from property sales not subject to federal obligations	$
y_{32}	Proceeds from property sales subject to grant obligations	$
y_{33}	Grant payments	$
y_{34}	Passenger facility charges	$
y_{35}	Other	$
y_{40}	Total number of passenger enplanements	Passengers
y_{50}	Total tons of cargo moved	Tons (#)

Table 3.3
Candidate Input Data (sub variables)

INPUT (x_n)	**DESCRIPTION** (Line item)	**UNITS**
x_{10}	Supplies, materials, repairs, maintenance	$
x_{20}	Communications and Utilities	$
x_{21}	Services	$
x_{22}	Insurance and claims	$
x_{23}	Government in lieu, permit, impact fees, etc.	$
x_{24}	Miscellaneous	$
x_{25}	Other	$
x_{30}	Personnel compensation and benefits	$
x_{40}	Debt service payments net of capitalized interest	$
x_{41}	Total reserve transfers	$
x_{42}	Total capital expenditures	$
x_{43}	Total other	$
	$\Sigma y_n = 27$ Outputs	
Total	$\Sigma x_n = 12$ Inputs	
	$\Sigma y_n + \Sigma x_n = 39$	

The variables in Table 3.4 and 3.5 are defined as follows :

y_1 = Total operating revenues (Aeronautical)

y_2 = Total operating revenues (Non-Aeronautical)

y_3 = Total non-operating revenues

y_4 = Total number of passenger enplanements

y_5= Total tons of cargo moved

x_1 = Maintenance Expenditures

x_2 = Operations Expenditures

x_3 = Staffing Expenditures

x_4 = Debt/Non-operating Expenditures

Table 3.4
Output Data Variables

Variable	Count	Make-up
y_1	1	Landing fees
	2	Terminal/International arrival area rental or other charges
	3	Apron charges/tiedowns
	4	Fuel flowage fees
	5	Utilities
	6	FBO revenue: contract or sponsor-operated
	7	Cargo and hangar rentals
	8	Securities reimbursement
	9	Miscellaneous
	10	Other
y_2	1	Rent/land rental
	2	Concessions
	3	Parking
	4	Rental cars
	5	In-flight catering
	6	Interest income
	7	Royalties from natural resource sales
	8	Miscellaneous
	9	Other
y_3	1	Bond Proceeds
	2	Proceeds from property sales not subject to Federal obligations
	3	Proceeds from property sales subject to grant obligations
	4	Grant payments
	5	Passenger facility charges
	6	Other
y_4	1	Total number of passenger enplanements
y_5	1	Total tons of Cargo moved
Total	27	Number of Output sub variables

The outputs listed in Table 3.4, and the inputs in Table 3.5 are extracted from the FAA financial forms found in Appendix A. These forms follow a standard accounting format, and lend themselves to general accounting practices. Both the outputs and inputs are directly related to each DMU, and there is consistency among the data variables. In addition, the sub-variable groupings are done in a manner that defines a specific operation resource or function. These in turn can be used to help differentiate where a problem exists when an inefficient DMU is found.

Table 3.5
Input Data Variables

Variable	Count	Make-up
x_1	1	Supplies, materials, repairs, maintenance
x_2	1	Communications and utilities
	2	Services
	3	Insurance and claims
	4	Government in lieu, permit, impact fees, etc.
	5	Miscellaneous
	6	Other
x_3	1	Personnel compensation and benefits
x_4	1	Debt service payments net of capitalized interest
	2	Total reserve transfers
	3	Total capital expenditures
	4	Total other
Total	12	Number of Input sub variables

ANALYSIS TOOLS

The CCR and BCC models shown in Chapter I were implemented using linear programming (LP). A short study was conducted to determine the best LP approach and to better understand the DEA algorithms. The primal formulations of the CCR and BCC have more variables than their dual formulations, and are therefore more computationally difficult for linear programs. Normally the dual approach is chosen due to this reason. Both the primal and dual identify the same number of efficient DMUs. There are several LP packages on the market. All these packages are capable of handling DEA algorithms, but do so with add-ons and templates (Anderson and Hollingswoth, 1997). LINDO (LINDO

Systems Inc.) was chosen to model the airport DEA model to become more familiar with the application of DEA. In addition there were DEA modeling software packages investigated. These consisted of IDEAS, Frontier, and DEAP (1 Consulting Inc., 1995; Banixa, 1997; and Coelli, 1996). Frontier is a relatively new DEA software package, and has outstanding graphical output. DEAP is a DEA application developed at the University of New England (Coelli, 1996). There is a student version of this application available and the documentation is very good. This package has been compared to more established DEA software, and is actually closely related to Frontier (Coelli, 1997). DEAP has the capability to add time domains to cover historical data trends.

The IDEAS DEA modeling package was chosen, but by no means does this imply that the other packages are not as capable. In fact they have some attributes that are more favorable, such as Windows based and graphical representation of analysis. IDEAS is capable of modeling all four of the DEA model types discussed in Chapter I. The version obtained is capable of solving a maximum of thirty DMUs and a maximum of ten outputs plus inputs (1 Consulting, 1995), and therefore capable of handling the DEA modeling defined within this thesis work. These maximums define a maximum number of cells that the version can handle, and equates to one-hundred and fifty cells. One may alter the number of DMUs, outputs, and inputs to any combination as long as the total cell count does not exceed one-hundred and fifty. There are other versions of IDEAS that can handle DEA models with a cell count of ten-thousand.

Stages one through five discussed in the beginning of this chapter have been covered up to now. Maximizing the output will require the DEA model to be input oriented. Either the CCR or the BCC model can be used. To determine which DEA model is best, first the selection of data to use is required. A total of twenty-seven outputs, and twelve inputs are available. If all these are to be used, then most likely every DMU would be found to be efficient. What is required is to select what variables best describe operational conditions of an airport. Since there are only sixteen total DMUs, the total number of outputs and inputs needs to be around five or less. Chapter IV discusses what variables will be selected to use in the DEA modeling.

CHAPTER IV

ANALYSIS OBJECTIVES

There are four objectives to this DEA study, they are :

- Determining the operational efficiency of each DMU within the total selected airport population (n_p),
- Determining the operational efficiencies of each DMU within the population of major airports (n_1), and regional airports (n_2),
- Understanding the influence each DMU has on another, and
- Determining which inputs for the determined inefficient DMUs require reductions, and to what level.

Working with the various populations (n_p, n_1, and n_2) insight into airport operational efficiencies will be obtained. Trends in input reductions may be found, and therefore application of these trends to other airports may be feasible.

During the DEA modeling, attention to basic DEA rules were followed. These rules are :

- A three to one ratio of DMUs to the summation of the number of outputs and inputs,
- The product of the number of outputs and inputs approximating the number of efficient DMUs, and
- The use of the CRS will reduce efficiency ratings, while the VRS raises them.

Comparisons will be made of the RTS between the CCR and the BCC models, and what efficient DMUs appear in each of the modeling approaches. As discussed earlier, IDEAS was chosen as the DEA modeling software package, and utilized in this thesis work (1 Consulting Inc. ,1995).

MODEL CONSTRUCTION

When building the DEA models, differentiation between the outputs and inputs is done to a level where it would be more identifiable as to where a problem existed in an inefficient DMU. Various data files were constructed within the IDEAS software package. Data files are files that contain output and input variables, relative to the DMU being modeled. Appendices D and E show the structure and contents respectively for the various data files. A total of thirteen data files were constructed during the analysis. Each model constructed utilizes a data file. Appendix F details the correspondence between models and data files. Each model was used to explore the number of efficient DMUs identified, based on the outputs and inputs used. Various mixtures of outputs and inputs were created to try and minimize the number of efficient DMUs. Table 4.1 shows data file structure; more detailed information can be found in Appendix D, through H regarding data file structure and model configurations.

The data files obtained from the FAA are in the Excel™ format. Each data file was developed within Excel™, and exported to an American Standard Code for Information Interchange (ASCII) text file. These ASCII text files were imported into IDEAS, and stored in the data file library. As a model was constructed, a data file was identified to be the source of the desired outputs and inputs used. These data files can be seen in Table 4.1, and Appendix D. IDEAS allows selection of which outputs and inputs are assigned to a specific model. Once the outputs and inputs are identified, then the model is coded with the desired orientation and evaluation techniques. Either output, or input orientations are selected. Both types of orientations were evaluated and it was decided that an input oriented model is more appropriate. All the inputs are proportionally reduced to allow the inefficient DMU to be efficient, and the output of that specific DMU is thus optimized.

The surface of the envelopment frontier is described as either a Constant Return to Scale (CRS) or a Variable Return to Scale (VRS). The majority of the models constructed were a CRS type. A CRS is generally used when an increase in output is directly proportional to the increase in input (Anderson, 1997). The evaluation techniques are the next characteristics that a model is provided with. The evaluation can be standard or units-invariant. Each of these can also take on a non-archimedean aspect; meaning the implementation of a two-phase solution approach as discussed in Chapter III. Standard evaluations are typically used when a model has a variety of units assigned to the outputs and inputs; this was the case in the early stages of the analysis. The initial models were exploratory, and were used to understand the way in which the data files interact within each model. In addition, variations in the total number of efficient DMUs based on model form, orientation, and evaluation technique were explored and their influences understood. It was essential that the data used was representative of airport operations. DEA models involve constraint matrices that are one hundred percent dense (Charnes, Cooper, Lewin and Seiford, 1994). Table 4.3, provides statistical data of the various outputs and inputs; Appendix I provides additional statistical information.

In oriented models (output or input oriented) the weighting assigned to each output and input are inversely proportional to the value ranges of the outputs and inputs. The larger the value range for the outputs or inputs, the smaller the values of the weights (Charnes, Cooper, Lewin and Seiford, 1994). The range of output variable (y_5) provided a larger weighting factor than any other output variable, the same is true for the input variable (x_1) relative to the other input variables. Having small weighting factors assigned to a variable can cause premature termination of the DEA algorithm.

The use of weighting ratios was employed in one model (AIR16XR) to explore influences regarding known ratios between various outputs and inputs. Ratios are used in DEA when there is a known reference. That reference may be a DMU that from past experience was known to be efficient. Ratios between the DMU's variables can be employed within a DEA model to further constrain it. Ratio constraints force the DEA model to pull from historical trends. Since the data being used was available only for a single fiscal year, it was determined that providing ratios to further constrain the model was not advisable until historical data was available to construct the appropriate ratios.

Table 4.1
Data File Structure

Data File	No. DMUs	Output/Input	Comments
AIRPORT	16	3/3	Combined operating revenue
AIRPORT1	12	3/3	Combined operating revenue, top 12 ranked airports
AIRPORT2	4	3/3	Combined operating revenue, 4 regional airports
AIRPORT3	16	5/4	Cargo added/Debt
AIRPORT4	12	5/4	Cargo added, top 12 ranked airports/debt
AIRPORT5	4	5/4	Cargo added, 4 regional airports/debt
AIRPORT6	16	4/4	Combined revenue + cargo/debt
AIRPORT7	12	4/4	Combined revenue + cargo/debt
AIRPORT8	4	4/4	Combined revenue + cargo/debt
AIRPORT9	16	5/4	Condensed + cargo/debt
AIRPORTA	16	4/4	Combined operating revenue, condensed + cargo/debt
AIRPORTB	12	4/4	Combined operating revenue, condensed + cargo/debt
AIRPORTZ	16	4/5	Same as AIRPORTA + Theoretical weather

It is not necessary for a model to use every output or input defined within the data file. Each output and input can be selected in a discretionary manner to represent the model formulation of interest. This explains the variations in the number of outputs to inputs between various models when using the same data file. There were a total of eighty models developed and analyzed, these can be found in Appendix F.

When conducting the analysis, high percentages of efficient DMUs per model were being encountered. There is a tendency for all models having a low ratio of DMUs to the total number of outputs and inputs, to produce a higher number of efficient DMUs. Table 4.2 provides a breakdown of the number of DMUs used in each model, and the average percentage of efficient DMUs relative to the average ratio of the number of DMUs to the total number of outputs and inputs. The percentage of efficient DMUs determined is of interest in helping to find a balance between the number of DMUs used to the total number of outputs and inputs used. A low number of DMUs using a high total of the number of outputs and inputs will result in a large number of efficient DMUs, and therefore poor differentiation between the DMUs. It will be shown later in this chapter how the number of outputs and inputs effected the number of efficient DMUs found, and what final model formulation was used to give the desired differentiation.

Table 4.2
Model Count and Percent of Efficient DMUs

Model Size	No. Developed	DMUs/O+I (Average)	% of Efficient DMUs Found (Average)
4 DMUs	13	0.73	76.92
12 DMUs	15	2.20	54.44
16 DMUs	52	2.91	54.45
Total	*80*		

Initially the data being utilized in the various DEA models had a wide numeric range and a variety of units. Wide variations in numeric range for a particular output or input variable can cause ill conditioning (Charnes, Cooper, Lewin and Seiford, 1994). Ill-conditioned data causes computational difficulties. IDEAS will identify when ill conditioning is present. An example of potential ill-conditioned data is variation in values from the tens to the millions. The data used in the models for this thesis work was considered to be well conditioned. Scaling was done to accommodate ease of data entry and editing. All the data utilized in the final model evaluations were considered discretionary. Earlier model runs incorporated non-discretionary data such as number of enplanements and tons of cargo moved; neither of these two are within the total control of a DMU. One model AIRZ01 was developed with theoretical weather percentages that corresponded to the percentage of days an airport was not operating. This data was generated to see what the effects on operational efficiencies may be. This was explored to see the impact of an input variable being non-discretionary.

The output and inputs listed in Table 4.3 have the following definition. The variables (y_n) and (x_n) are shown in Table 3.2 and 3.3 respectively.

$$y_1 = y_{10} + y_{11} + y_{12} + y_{13} + y_{14} + y_{15} + y_{16} + y_{17} + y_{18} + y_{19}$$

$$y_2 = y_{20} + y_{21} + y_{22} + y_{23} + y_{24} + y_{25} + y_{26} + y_{27} + y_{28}$$

$$y_3 = y_{30} + y_{31} + y_{32} + y_{33} + y_{34} + y_{35}$$

$$y_4 = y_{40}$$

$$y_5 = y_{50}$$

$$x_1 = x_{10}$$

$$x_2 = x_{20} + x_{21} + x_{22} + x_{23} + x_{24} + x_{25}$$

$$x_3 = x_{30}$$

$$x_4 = x_{40} + x_{41} + x_{42} + x_{43}$$

$$y_1^* = y_{10} + y_{11} + y_{12} + y_{13} + y_{14} + y_{15} + y_{16} - y_{17} - y_{18} - y_{19} + y_{20} + y_{21} + y_{22} + y_{23} + y_{24} + y_{25} - y_{26} + y_{27} - y_{28}$$

$x_2^* = x_{20} + x_{21} + x_{22} - x_{23} + x_{24} - x_{25}$

Table 4.3
Output and Input Statistical Data

Output/Input	Mean	Median	Range	Min	Max
y_1	114.9276	73.5681	418.6375	2.5265	421.1640
y_2	99.6878	104.2700	310.5476	2.7044	313.2520
y_3	209.4242	125.2420	624.6350	2.8210	627.4650
y_4	12.4938	13.2374	27.7678	0.3231	28.0910
y_5	0.5601	0.3706	1.5746	0.0226	1.5972
x_1	19.8634	8.9175	72.2833	0.5047	72.7880
x_2	48.2852	24.5322	160.8144	0.7276	161.5420
x_3	42.0921	28.2121	133.5127	1.5543	135.0670
x_4	252.3417	232.8210	817.2733	3.4048	820.6781
y_1*	209.5838	175.6531	518.6710	5.2309	523.9020
x_2*	24.9007	18.0704	84.9123	0.3967	85.3090

VARIOUS MODEL FORMULATIONS

Initial modeling did not use the non-archimedean constant (ε), and therefore a two stage optimization was not used. To understand the impact of this, an LP was written using LINDO. This LP was for a dual CRS model, and (ε) was estimated to be .001. This is not recommended for an actual analysis because it can lead to inaccurate results as previously discussed. This was only done to understand the role of (ε) in DEA modeling. In addition the program DEAP (Coelli, 1996) was used to compare the results to the LINDO DEA LP; the results from both methods were consistent. This exercise in (ε) was strictly to gain further insight into its influence in DEA modeling. IDEAS eliminates the need to calibrate (ε) by a preemptive approach.

As mentioned earlier, a total of eighty models were developed and analyzed. For discussion purposes, seven of these models will be explained. All seven of these models follow the general rules regarding DEA modeling techniques outlined in the beginning of this chapter. The models shown in Table 4.4 are input oriented, and utilize (ε). Each model produced relative efficiency scores with varying results, yet provided consistency in the DMUs determined to be efficient, i.e., (θ=1). Table 4.5 lists each DMU, and their respective efficiencies, for the models identified in Table 4.4. The shaded areas in Table

* denotes the combination and removal of sub variables in defining the output and input for the models AIRW06C, AIRW06D, and AIRW06V.

4.5 identify the efficient DMUs. The repeatability of efficient DMUs in each model can be seen, as well as the model type and size has on the number of efficient DMUs determined.

Table 4.4
Model Comparisons

Model	DMUs	O/I	Form	Data File	$\theta = 1$	Remarks
AIR16	16	3/3	CRS	AIRPORT	8	
AIR12	12	3/3	CRS	AIRPORT1	6	
AIR16X	16	5/4	CRS	AIRPORT3	13	
AIR12X	12	5/4	CRS	AIRPORT4	10	
AIRW06C	16	1/3	CRS	AIRPORTA	4	Minus y2, y3, y4 and x4
AIRW06D	12	1/3	CRS	AIRPORTB	4	Minus y2, y3, y4 and x4
AIRW06V	16	1/3	VRS	AIRPORTA	9	Minus y2, y3, y4 and x4

DATA ENVELOPMENT ANALYSIS MODEL RESULTS

Modeling was done to begin the process of differentiating between efficient and inefficient airports. Initial models used a three output, three input formulation. These formulations were comprised of the variables listed in Appendix D. The model AIR16 utilizes all sixteen DMUs (n_p), and the model AIR12 utilizes just the top ranked airports based on yearly enplanements (n_1). Both models are identical with respect to the outputs and inputs that are utilized during the DEA procedure. Model AIR16 found eight efficient DMUs. Out of the group of eight efficient DMUs, two of those were from regional airports (n_2). Model AIR12 was developed to understand the influence that the four regional airports may have in determining the efficient airports from the top ranked twelve, and found six efficient DMUs. Every efficient DMU from model AIR16 was also found in model AIR12. The inefficient DMUs were determined to be as inefficient with the exception of DMU MIA (Miami). This one difference suggests that the four DMUs that make up the regional airports contribute to the inefficiency of DMU MIA. In model AIR16 the two additional efficient DMUs RDU, and RIC changed to reference set of MIA, and therefore its efficiency rating. Had no additional efficient DMUs been found in AIR16, then MIA's efficiency rating would of not changed. Reference sets will be discussed later in this chapter. The data files used for these two models, as well as the others are listed in Appendix F. In an effort to obtain more differentiation, the data was reviewed further. The number of efficient DMUs defined from models AIR16 and AIR12 was higher than desired; higher differentiation between all sixteen DMUs was desired.

Table 4.5
Model Efficiency Comparisons

DMU	NAME	AIR16	AIR12	AIR16X	AIR12X	AIRW06C	AIRW06D	AIRWO6V
1	ATL	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
2	LAX	1.0000	1.0000	1.0000	1.0000	0.9636	0.9636	1.0000
3	SFO	0.5991	0.5991	1.0000	1.0000	0.4668	0.4993	0.4996
4	MIA	0.4400	0.4447	0.9157	0.9747	0.4145	0.4145	0.4187
5	DEN	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
6	JFK	0.7159	0.7159	1.0000	1.0000	0.7730	0.7730	1.0000
7	PHX	0.8947	0.8947	1.0000	1.0000	0.6911	0.6911	0.7123
8	LAS	1.0000	1.0000	1.0000	1.0000	0.9176	0.9176	0.9361
9	EWR	0.7041	0.7041	1.0000	1.0000	0.6831	0.6831	0.6879
10	STL	1.0000	1.0000	1.0000	1.0000	0.8073	0.8073	0.8381
11	MSP	0.7587	0.7587	0.9036	0.9373	0.8741	1.0000	1.0000
12	BOS	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
13	RDU	1.0000		1.0000		1.0000		1.0000
14	ORF	0.5704		0.9060		0.5065		0.7025
15	RIC	1.0000		1.0000		0.7674		1.0000
16	ROA	0.5067		1.0000		0.4603		1.0000
θ=1		8	6	13	10	4	4	9

It was decided to increase the number of outputs and inputs to try and provide insight to a potential problem area within a defined operational function. Models AIR16X and AIR12X utilized a five output, four input configuration. The outputs were increased from three to five by separating (y_1) into two outputs, operating revenues aeronautical and non-aeronautical, and adding number tons of cargo (y_5) moved. The additional input debt and non-operating expenditures (x_4), increased the number of inputs to four. Models AIR16X and AIR12X utilized the new outputs and inputs. The number of efficient DMUs increased to thirteen and ten respectively. This was expected since the product of the number of outputs and inputs was twenty. Recall the general rule regarding the number of efficient DMUs and its relationship to the product of the number of outputs and inputs. It was hoped that with more differentiation of the outputs and an additional input, the number of efficient DMUs determined would drop, and thus provide insight into those variables resulting in efficient DMUs.

Since an input oriented model was used, the variables (θ) and (λ) are the only variables that have nonzero values. All other basic variables have a value of zero, making this basis degenerate. Models that have degeneracy may require significant amount of computation before optimality is reached. With the simplex algorithm, degenerate pivots are performed each time no improvement in the objective value occurs. As the number of the outputs and inputs increases, the probability of encountering degenerate pivots increases due to the basic solution having a larger number of variables equal to zero (Charnes, Cooper, Lewin and Seiford, 1994). In the case of models AIR16X and AIR12X, the small number of inefficient DMUs is directly associated with the large number of outputs and inputs.

The next iteration in the analysis was focused on redesigning the number of outputs and inputs. Models AIRW06C, AIRW06D, and AIRW06V were built. These models utilized a single output and three inputs. Further evaluation and understanding of DEA led to the following decisions.

- Focus DEA modeling specifically on daily airport operations,
- Consistency in data across all DMUs, and
- Combining sub variables that are closely related.

Point one is simply to focus the DEA modeling on determining which airports are efficient on a daily operating basis. The aeronautical and non-aeronautical operating revenues were combined to provide a total operating revenue (y_1*). Non-operating revenues (bonds and grants) were not used due to some of the DMUs having a value of zero in this category. Although there are ways to deal with variables that have a value of zero, for consistency they were removed. This is also the reason input variable (x_4) was removed in the final formulation. The inputs utilized are (x_1, x_2*, and x_3). The removal of other sub-variables that in turn make up a variable was done with the same reasoning used as that with bonds and grants. Appendix D, shows models AirportA and AirportB, and which sub-variables were removed within each variable. The final DEA model consisted of outputs and inputs that focus on daily monetary operational efficiency. In this case all the units are in dollars ($) and therefore we are not using one of the most favorable functions of DEA, the ability to handle multiple units of measure. This raises the question of why even use DEA? Can not we accomplish efficiency measures by using standard efficiency measures? These questions will be addressed in full later in this chapter.

VARIATIONS IN OUTPUT AND INPUT

As discussed earlier DEA provides the ability to use multiple outputs and inputs as well as multiple units. The model AIRW06C is used to compare efficiency measures using the DEA approach and the standard efficiency approach. Models AIRW06C, AIRW06D, and AIRW06V utilized a singular output and three inputs. Models AIRW06C and AIRW06D found the same four efficient DMUs. The difference between these two models is that AIRW06C includes sixteen DMUs, and AIRW06D twelve DMUs. Out of the four efficient DMUs in model AIRW06C, one was from the population sampling of regional airports. The model AIRW06D does not use the population sampling of regional airports, yet still had four efficient DMUs; Minneapolis (MSP) became the fourth efficient DMU in this model. Table 4.5, shows the efficient DMUs for models AIRW06C and AIRW06D, Table 4.6 shows the differences. The percent differences shown in Table 4.6 illustrate the influence that each efficient DMU has upon the other DMUs. When the population sample of regional airports was removed in model AIRW06D, the efficiency rating for San Francisco (SFO) increased and Minneapolis (MSP) became efficient, the efficiencies of the other DMUs remained constant. The increase in SFO and MSP is a direct result of the removal of the population sample for regional airports, therefore each of the regional airports effect the efficiency rating for SFO and MSP. The reason why the efficiencies of these two DMUs changed is because of the reference sets used for each DMU changed when the regional airports were removed from the DEA model. In AIRW06C, SFO uses DEN, ATL, and RDU as its reference set to determine its efficiency of 0.4668. DMU MSP uses DEN and RDU in the DEA model AIRW06C to obtain an efficiency rating of 0.8741. When DEA model AIRW06D is used, the regional airports are not considered. The reference set for SFO in this case changes to DEN, ATL, and MSP and increases efficiency to 0.4993. DMU MSP becomes efficient and therefore references itself. The two DMUs SFO and MSP demonstrate how the regional airports do effect the efficiency ratings. When the regional airports are included in the DEA modeling, therefore model AIRW06C; RDU efficiently operates with the defined variables used. Reference sets will be discussed later in this chapter.

Model AIRW06V is a VRS model. This model determines its efficiency frontier utilizing convexity constraints. As expected, the number of efficient DMUs increased due to these convexity constraints. The efficient DMUs generated in model AIRW06V are repeated in model AIRW06C. When MSP was added to the list of efficient DMUs in model AIRW06D, it agreed with model AIRW06V relative to the same DMUs from model AIRW06C and the DMU MSP. The sample of regional airports in model AIRW06V generated a total of three efficient DMUs vise one in model AIRW06C. Frontier plots of each model are provided in Figures 4.1.a through 4.1.c. The dashed lines show the actual adjustment to the efficiency frontier. Inefficiency values in model AIRW06V were slightly higher as expected.

SLACK VARIABLE IMPACTS

Looking at the efficiency values that were determined, and comparing them to the radial plots of each DMU in Figures 4.1.a through Figures 4.1.c, we can see the relationship between the efficiency value and the percentage of the radial line length crossing the efficiency frontier. The DMUs that do not have this direct relationship contain slack. Where the radial efficiency line intersects the efficiency frontier, the percentage of the radial line from the origin to that intersection point equates to the efficiency rating of the DMU of interest. In addition, where the radial line intersects the efficiency frontier is the position of the respective DMU on the efficiency frontier, and those efficient DMUs in close proximity make up the reference set for that inefficient DMU. A reference set is determined for each DMU. Each DMU is compared one at a time against all the other DMUs within the DEA model. After all DMUs have been evaluated, and those determined efficient ($\theta=1$), the inefficient DMUs are analyzed and required reductions in inputs determined. These reductions are done by comparing the inefficient DMUs to the efficient DMUs. Each inefficient DMU has a reference set determined that best suits its ability to provide its best efficiency. The importance of the reference set is associated with the amount of an efficient DMU an inefficient DMU uses to determine the proportional reductions in inputs.

There can be more than one DMU in a reference set. Lambda (λ_j) is the variable that defines the amount of an efficient DMU to be used. In Table 4.8, the values of lambda are listed for model AIRW06C. An efficient DMU has a (λ_j) value of one, and references itself. In a VRS model, (λ) is equal to one for an efficient DMU and the summation of (λ_j)'s in a reference set is always equal to one; this can be seen in Equation (5). In a CRS model, (λ) is always equal to one for an efficient DMU, but the values of lambda in the reference set can sum to a value less than, equal to, or greater than one. This is one reason a CRS model is able to calculate a lesser amount of efficient DMUs. Letting inefficient DMUs use more of an efficient DMU allows the algorithms to restrict the number of efficient DMUs. In the VRS model, lambda is confined to being equal to one, and therefore the number of efficient DMUs is usually greater.

Table 4.6
Efficiency Percentage Differences Compared Against AIRW06C

DMU	NAME	AIRW06C	AIRW06D	% Difference	AIRWO6V	% Difference
1	ATL	1.0000	1.0000	0.000%	1.0000	0.000%
2	LAX	0.9636	0.9636	0.000%	1.0000	3.778%
3	SFO	0.4668	0.4993	6.962%	0.4996	7.027%
4	MIA	0.4145	0.4145	0.000%	0.4187	1.013%
5	DEN	1.0000	1.0000	0.000%	1.0000	0.000%
6	JFK	0.7730	0.7730	0.000%	1.0000	29.366%
7	PHX	0.6911	0.6911	0.000%	0.7123	3.068%
8	LAS	0.9176	0.9176	0.000%	0.9361	2.016%
9	EWR	0.6831	0.6831	0.000%	0.6879	0.703%
10	STL	0.8073	0.8073	0.000%	0.8381	3.815%
11	MSP	0.8741	1.0000	14.403%	1.0000	14.403%
12	BOS	1.0000	1.0000	0.000%	1.0000	0.000%
13	RDU	1.0000			1.0000	0.000%
14	ORF	0.5065			0.7025	38.697%
15	RIC	0.7674			1.0000	30.310%
16	ROA	0.4603			1.0000	117.250%

There is also a relationship between lambda and the efficiency frontier. The DMU Los Angeles (LAX) uses as a reference set the efficient DMUs Boston (BOS) and Denver (DEN). Figure 4.2.a shows that LAX is projected on the efficiency frontier between BOS and DEN. There are cases such as the inefficient DMU Newark (EWR) that use only one efficient DMU, DEN. Others use more, such as San Francisco (SFO), which uses efficient DMUs Atlanta (ATL), DEN, and Raleigh (RDU). These reference sets are shown in Table 4.8.

Three of the inefficient DMUs did not project onto the efficiency frontier as expected with their radial efficiency lines, this was due to large slack values. Slack values for each model are shown in Table 4.7. Using model AIRW06C to demonstrate this, we can see in Figure 4.1.a, that LAX, John F. Kennedy (JFK), and EWR the proportions of their radial efficiencies do not match the efficiency ratings determined in the DEA model. This is not an error, but can be explained by their corresponding slack values. Their actual projections onto the efficiency frontier are shown in Figure 4.2.a. The following analysis shows the calculations of the projected values for these three DMUs. By definition, an efficient DMU not only has a value of one for (θ), but does not have any slack. Inefficient DMUs having slack will not project unto the efficiency frontier along their radial efficiency lines emanating from the origin. The three DMUs LAX, JFK, and EWR have the largest slack, and therefore will be used to show the calculations of actual projection points, but this analysis applies to all inefficient DMUs.

LAX

$\theta = .96$ $\quad x_1/y_1^* = .038231$ $\quad x_2^*/y_1 = .232300$

$(x_1/y_1^*)(\theta) = \Delta$

$(.038231)(.96) = .036702$

$(x_2^*/y_1^*)(\theta) = \beta$

$(.232300)(.96) = .223008$

There is only slack in input (x_2^*) for this inefficient DMU. The values (Δ) and (β) are the projected (x) and (y) coordinates for DMU LAX from the origin. These were determined by multiplying the efficiency score of the DMU to the corresponding coordinates to demonstrate that the inefficient DMU does not project onto the efficiency frontier along the radial efficiency line. To move the inefficient DMU onto the efficiency frontier, slack for the variables needs to be considered. The variable ($x^s{}_2^*$) represents the slack in variable (x_2^*), and will define the additional movement the DMU needs to take.

Slack :

$x^s{}_2^* = 44.17$

$y_1^* = 367.24$

$x^s{}_2^*/y_1^* = \omega$

$44.17/367.24 = .120276$

The value of (ω) is projected down the ordinate from the DMUs original position. Each of the values (ω), (Δ) and (β) can be seen on Figure 4.1.a. The same analysis approach holds true for DMU EWR and JFK.

EWR

$\theta = .68$ $x_1/y_1{*} = .200043$ $x_2{*}/y_1{*} = .104715$

$(x_1/y_1{*})(\theta) = \Delta$

$(.200043)(.68) = .136027$

$(x_2{*}/y_1{*})(\theta) = \beta$

$(.104715)(.68) = .071206$

Slack :

$x^s_1 = 29.56$

$x^s_2{*} = 1.24$

$y_1{*} = 328.13$

$x^s_1/y_1{*} = \tau$

$29.56/328.1250 = .090086$

$x^s_2{*}/y_1{*} = \omega$

$1.24/328.1250 = .003279$

JKF

$\theta = .77$ $x_1/y_1{*} = .1389349$ $x_2{*}/y_1{*} = .078736$

$(x_1/y_1{*})(\theta) = \Delta$

$(.138939)(.77) = .106983$

$(x_2{*}/y_1{*})(\theta) = \beta$

$(.\ 078736)(.77) = .060627$

Slack :

$x^s_1 = 22.53$

$y_1{*} = 523.9020$

$x^s_1/y_1{*} = \omega$

$22.53/523.9020 = .043040$

Table 4.7
Slack Values for Models AIRW06C, AIRW06D, and AIRW06V

		AIRW06C			AIRW06D			AIRW06V		
DMU	NAME	x_1	x_2*	x_3	x_1	x_2*	x_3	x_1	x_2*	x_3
1	ATL	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	LAX	0.000	44.170	0.000	0.000	44.170	0.000	0.000	0.000	0.000
3	SFO	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.140
4	MIA	0.000	1.300	0.000	0.000	1.300	0.000	0.000	0.000	1.690
5	DEN	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	JFK	22.530	0.000	0.000	22.530	0.000	0.000	0.000	0.000	0.000
7	PHX	0.000	4.120	0.000	0.000	4.120	0.000	0.000	4.260	0.000
8	LAS	0.000	0.000	4.770	0.000	0.000	4.770	0.000	0.000	4.280
9	EWR	29.560	1.240	0.000	29.560	1.240	0.000	29.800	1.260	0.000
10	STL	0.000	0.900	0.000	0.000	0.900	0.000	0.000	0.950	0.000
11	MSP	0.000	0.000	6.230	0.000	0.000	0.000	0.000	0.000	0.000
12	BOS	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
13	RDU	0.000	0.000	0.000	-	-	-	0.000	0.000	0.000
14	ORF	0.000	0.080	0.000	-	-	-	0.000	0.140	0.000
15	RIC	0.000	0.000	0.750	-	-	-	0.000	0.000	0.000
16	ROA	0.000	0.000	0.020	-	-	-	0.000	0.000	0.000

Table 4.8
Lambda Values for Model AIRW06C

DMU	THETA	ATL	DEN	BOS	RDU
ATL	1.00	1.0000	0.0000	0.0000	0.0000
LAX	0.96	0.0000	0.3462	0.9663	0.0000
SFO	0.47	0.1286	0.3764	0.0000	1.5243
MIA	0.41	0.0000	0.9353	0.1065	0.0000
DEN	1.00	0.0000	1.0000	0.0000	0.0000
JFK	0.77	0.8642	0.8140	0.0000	0.0000
PHX	0.69	0.0000	0.2406	0.1101	0.0000
LAS	0.92	0.0000	0.3611	0.0554	0.0000
EWR	0.68	0.0000	0.7142	0.0000	0.0000
STL	0.81	0.0000	0.0735	0.3122	0.0000
MSP	0.87	0.0000	0.0930	0.0000	1.9042
BOS	1.00	0.0000	0.0000	1.0000	0.0000
RDU	1.00	0.0000	0.0000	0.0000	1.0000
ORF	0.51	0.0000	0.0191	0.0311	0.0000
RIC	0.77	0.0000	0.0066	0.0716	0.0000
ROA	0.46	0.0000	0.0100	0.0031	0.0000

Table 4.9.a
Original and Projected Data Points for Model AIRW06C

	Original				Projected			
ID	y_1^*	x_1	x_2^*	x_3	$y'_1{}^*$	x'_1	$x'_2{}^*$	x'_3
ATL	173.50	18.89	7.58	25.08	173.5	18.89	7.58	25.08
LAX	367.24	14.04	85.31	70.14	367.24	13.53	38.03	67.58
SFO	244.50	32.58	28.48	70.70	244.5	15.21	13.29	33
MIA	452.61	49.90	80.63	135.07	452.61	20.68	32.12	55.98
DEN	459.43	21.39	31.13	54.11	459.43	21.39	31.13	54.11
JFK	523.90	72.79	41.25	85.01	523.9	33.74	31.89	65.72
PHX	134.23	8.45	21.29	26.88	134.23	5.84	10.59	18.58
LAS	177.81	8.80	13.95	29.54	177.81	8.07	12.8	22.33
EWR	328.13	65.64	34.36	56.57	328.13	15.28	22.23	38.64
STL	100.95	4.39	14.85	24.47	100.95	3.55	11.09	19.75
MSP	104.31	9.04	4.18	26.34	104.31	7.9	3.65	16.8
BOS	215.26	6.33	28.19	50.53	215.26	6.33	28.19	50.53
RDU	32.33	3.10	0.40	6.18	32.33	3.1	0.4	6.18
ORF	15.48	1.20	3.07	5.14	15.48	0.61	1.47	2.61
RIC	18.44	0.77	2.90	6.16	18.44	0.59	2.22	3.97
ROA	5.23	0.50	0.86	1.55	5.23	0.23	0.4	0.69

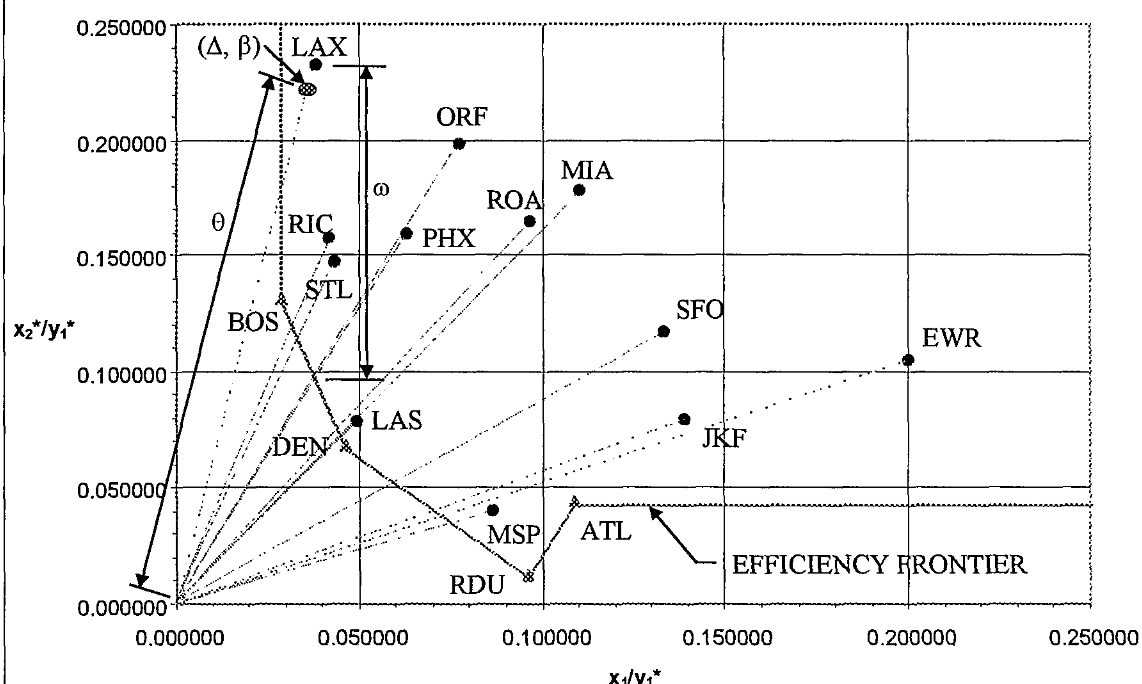

Figure 4.1.a. Efficiency Frontier for Model AIRW06C

Table 4.9.b
Original and Projected Data Points for Model AIRW06D

	Original				Projected			
ID	y_1*	x_1	x_2*	x_3	y'_1*	x'_1	x'_2*	x'_3
ATL	173.50	18.89	7.58	25.08	173.5	18.89	7.58	25.08
LAX	367.24	14.04	85.31	70.14	367.24	13.53	38.03	67.58
SFO	244.50	32.58	28.48	70.70	244.5	16.27	14.22	35.3
MIA	452.61	49.90	80.63	135.07	452.61	20.68	32.12	55.98
DEN	459.43	21.39	31.13	54.11	459.43	21.39	31.13	54.11
JFK	523.90	72.79	41.25	85.01	523.9	33.74	31.89	65.72
PHX	134.23	8.45	21.29	26.88	134.23	5.84	10.59	18.58
LAS	177.81	8.80	13.95	29.54	177.81	8.07	12.8	22.33
EWR	328.13	65.64	34.36	56.57	328.13	15.28	22.23	38.64
STL	100.95	4.39	14.85	24.47	100.95	3.55	11.09	19.75
MSP	104.31	9.04	4.18	26.34	104.31	9.04	4.18	26.34
BOS	215.26	6.33	28.19	50.53	215.26	6.33	28.19	50.53

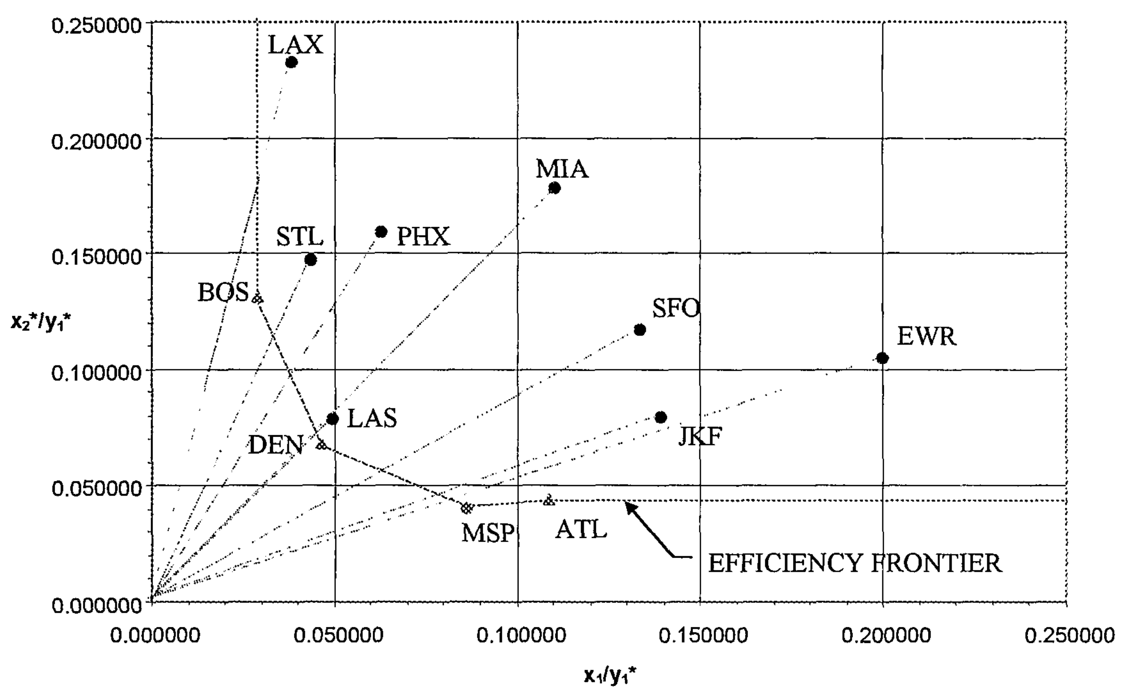

Figure 4.1.b. Efficiency Frontier for Model AIRW06D

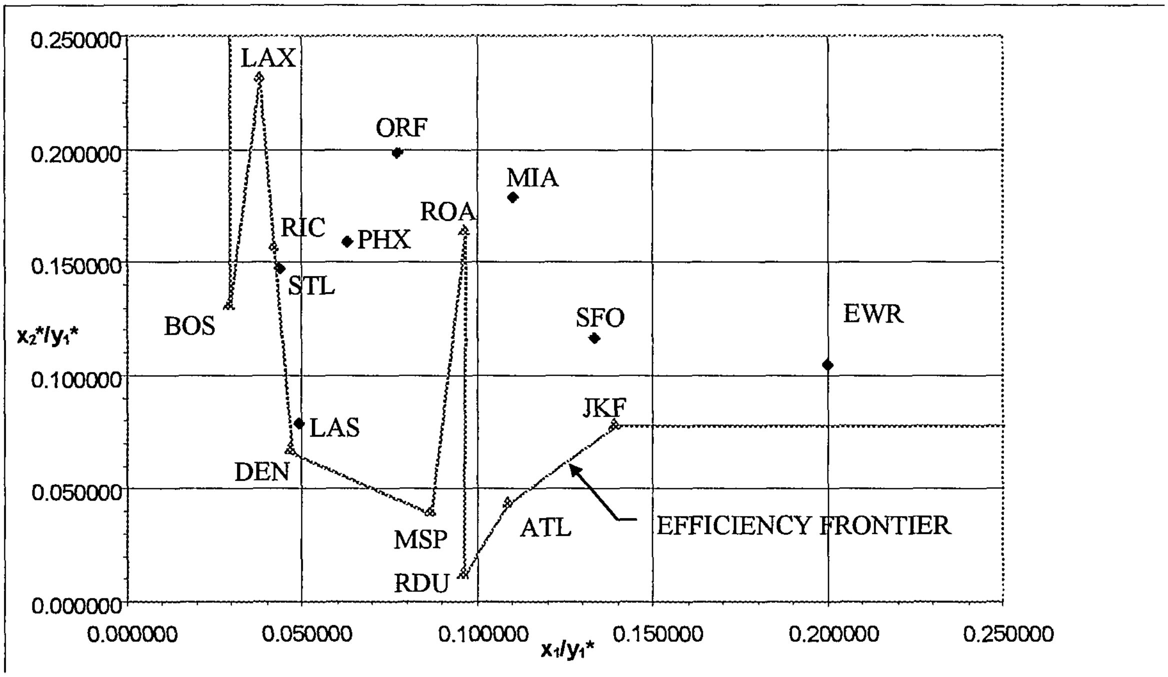

Figure 4.1.c. Efficiency Frontier for Model AIRW06V

Table 4.9.c
Original and Projected Data Points for Model AIRW06V

	Original				Projected			
ID	y_1*	x_1	x_2*	x_3	y'_1*	x'_1	x'_2*	x'_3
ATL	173.50	18.89	7.58	25.08	173.50	18.89	7.58	25.08
LAX	367.24	14.04	85.31	70.14	367.24	14.04	85.31	70.14
SFO	244.50	32.58	28.48	70.70	244.50	16.28	14.23	35.18
MIA	452.61	49.90	80.63	135.07	452.61	20.89	33.76	54.86
DEN	459.43	21.39	31.13	54.11	459.43	21.39	31.13	54.11
JFK	523.90	72.79	41.25	85.01	523.90	72.79	41.25	85.01
PHX	134.23	8.45	21.29	26.88	134.23	6.02	10.90	19.15
LAS	177.81	8.80	13.95	29.54	177.81	8.24	13.06	23.38
EWR	328.13	65.64	34.36	56.57	328.13	15.35	22.38	38.91
STL	100.95	4.39	14.85	24.47	100.95	3.68	11.49	20.51
MSP	104.31	9.04	4.18	26.34	104.31	9.04	4.18	26.34
BOS	215.26	6.33	28.19	50.53	215.26	6.33	28.19	50.53
RDU	32.33	3.10	0.40	6.18	32.33	3.10	0.40	6.18
ORF	15.48	1.20	3.07	5.14	15.48	0.84	2.01	3.61
RIC	18.44	0.77	2.90	6.16	18.44	0.77	2.90	6.16
ROA	5.23	0.50	0.86	1.55	5.23	0.50	0.86	1.55

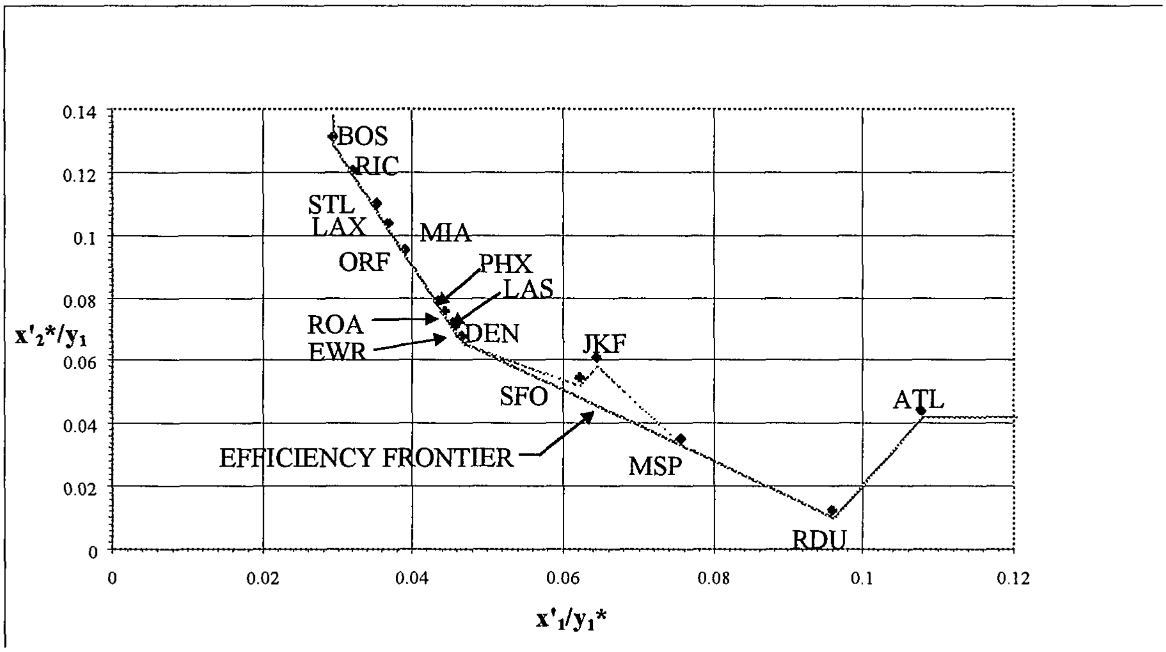

Figure 4.2.a. Projected DMUs for Model AIRW06C

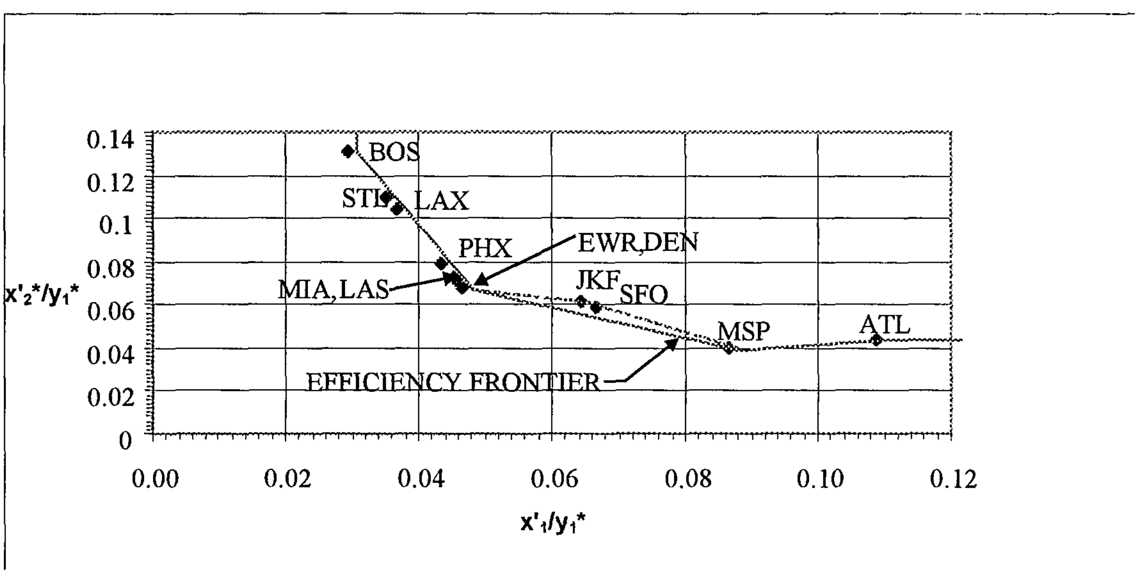

Figure 4.2.b. Projected DMUs for Model AIRW06D

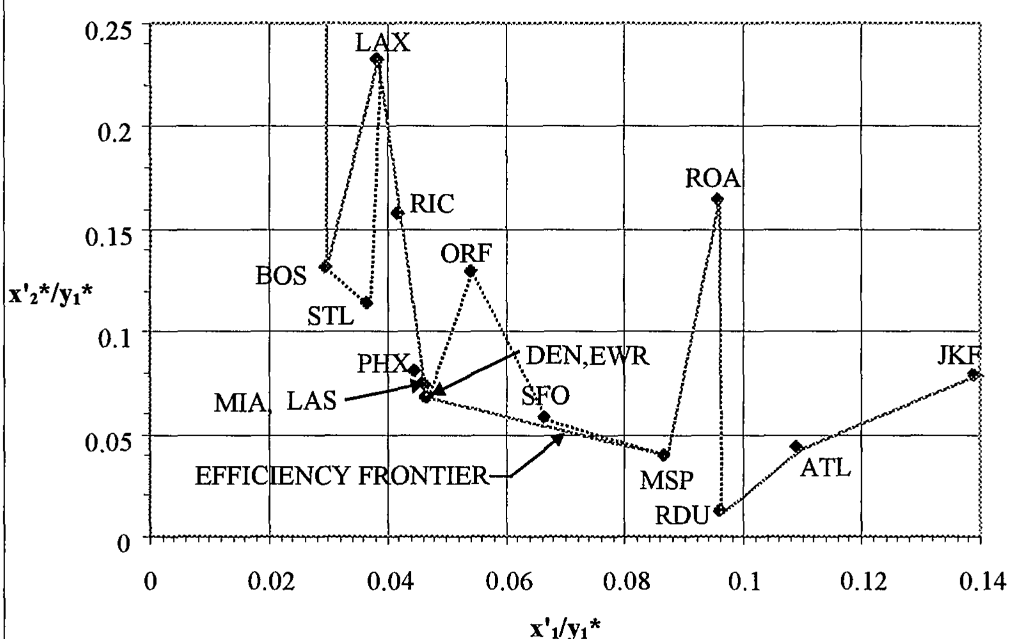

Figure 4.2.c. Projected DMUs for Model AIRW06V

EFFICIENCY COMPARISONS

Final selection of data variables resulted in all the units becoming dollars ($). One may use standard efficiency measures in this case. Again using model AIRW06C, a demonstration showing the difference between standard efficiency and DEA efficiency will be done. Table 4.10 shows efficiency measures for both approaches. The model already utilizes a singular output (y*). Summing the inputs (x_1, x_2* and x_3) yields (Σx), which provides a singular input. Using equation (7), the standard efficiency measures, ($y/\Sigma x$) is determined. The highest DMU ratio was assigned an efficiency value of one, and the other DMU ratios were determined by normalizing against the efficient DMU. The standard efficiencies for all the DMUs are provided in the far right column of Table 4.10.

DEA found four efficient DMUs in model AIRW06C; ATL, BOS, DEN, and RDU. When the standard efficiency approach is used, typically only one DMU can equate to an efficiency rating of one. Looking at the top four DMUs utilizing standard efficiencies, three of the DEA efficient DMUs are included, yet their efficiency ratings range from 1.000 to 0.775. The fourth DMU found efficient with the DEA approach was BOS, with a standard efficiency rating of 0.587. There are two primary reasons why DEA determines four efficient DMUs and the standard efficiency rating only one. The first is the use of lambda (λ). Recall that lambda can be equal to, less than, or greater than one in the summation of lambda for a reference set in a CRS model, and equal to one for a VRS model. DEA efficiencies are determined from a reference set. The algorithm is repeated for each DMU, and the result is a reference set for each inefficient DMU. This reference set is used to determine what changes in the outputs or inputs occur. The standard efficiency measure only uses one DMU as its reference. In this case it is DEN. The second reason for the efficiency differences deals with the weighting factors. In the standard efficiency measure, both the output and input are weighted the same, meaning their level of importance is equal. This approach does not allow differentiation between the various outputs or inputs that exist because they were summed together. The DEA approach allows each variable for each DMU to assume an optimal weight. In the case of model AIRW06C, each input (x_1, x_2*, and x_3) has its own weight and therefore its own level of importance relative to a specific DMU. This allows differentiation, which in turn provides insight to where an efficiency problem may occur. The DMU DEN, yields an efficiency rating of one (1.00) by using the (E) and DEA approach. Table 4.10.a shows the projection comparisons between (E) and (θ). When the (E) approach is used every input assumes the same weighting (level of importance), and DEN is the only reference point. In DEA, each input is determined to have an optimized weight by using the efficient DMUs as a reference set for the inefficient DMUs in question. In this case, LAX used DEN and BOS to proportionately reduce its input variables. The level of importance for each input variable is associated with its assigned weight.

When comparing (E) to DEA modeling, there are three reasons why the (E) method is not desirable when comparing organizations or process efficiencies.

1. All inputs assume same level of importance (weighting),
2. Only one reference DMU, and
3. No consideration given to slack in variables.

These points highlight the importance of using DEA over (E) methods. As an example, the reference set and weighting differences between (θ) and (E) can be seen in DMU LAX. The example follows :

Requirements :

1. Hold output (y_1*) constant, and
2. Vary the values of the inputs to set (E) and (θ) equal to one (1.00)

Given :

(E) and (θ) for DEN = 1.00

(E) for LAX = .503

(θ) for LAX = .9636

Output and Inputs for LAX :

y_1* = 367.24, x1 = 14.04, x_2* = 85.31, x_3 = 70.14

Reference Set(s) for LAX:

(E) = DEN (1.00)

(θ) = DEN (.34662) + BOS (.9663) = 1.3129

By (E) :

LAX $y_1* = 367.24$ $\Sigma x = 169.49$

$y_1*/\Sigma x = 367.24/169.49 = 2.17$

DEN $y_1* = 459.43$ $\Sigma x = 106.63$

$y_1*/\Sigma x = 459.43/106.63 = 4.31$

To make LAX equivalent to DEN, then :

$y_1*/\Sigma x\ (DEN) = y_1*(LAX)/\sigma_I$ σ_I = Projected input for (E)

$4.31 = 367.24/\sigma_I$

$\sigma_I = 85.21$

Each input (x_1, x_2*, and x_3) is weighted the same, therefore to achieve (σ_I), each input needs to be reduced by (E).

For LAX :

$x_1(E) + x_2*(E) + x_3(E) \approx \sigma_I$

$14.04(.503) + 85.31(.503) + 70.14(.503) = 85.25$

Using the (E) approach, each input was reduced the same, and therefore no attempt to optimize the input reduction. One input may require a greater reduction than another, or a smaller amount than another to achieve an optimal solution.

By (θ) :

LAX $y_1* = 367.24$ $x'_1 = 13.53$ $x'_2* = 38.03$ $x'_3 = 67.58$

Determined weights by IDEAS :

$y_1* = .00262$ $x_1 = .04109$ $x_2* = EPS$ $x_3 = .00603$ EPS = (ε)

To project to the efficiency frontier :

$y_1*(u_1) - x'_1(v_1) - x'_2(v_2) - x'_3(v_3) = 0$

$367.24(.00262) - 13.53(.04109) - 38.03(EPS) - 67.58(.00603) = 0$

$.9622 - .5559 - 38.03(EPS) - .4075 = 0$

$-38.03(EPS) = .0012 \approx 0$

EPS = .00003155 (By DEA) Recall that the use of (ε) ensures every input is utilized no matter how small.

Table 4.10
DEA Efficiencies (θ) and Standard Efficiencies (E) for Model AIRW06C
(E) Arranged In Descending Order

ID	y_1*	x_1	x_2*	x_3	θ	y*	Σx	y/Σx	ID	E
ATL	173.50	18.89	7.58	25.08	1.00	173.50	51.55	3.37	DEN	1.000
LAX	367.24	14.04	85.31	70.14	0.96	367.24	169.49	2.17	LAS	0.789
SFO	244.50	32.58	28.48	70.70	0.47	244.50	131.76	1.86	ATL	0.781
MIA	452.61	49.90	80.63	135.07	0.41	452.61	265.59	1.70	RDU	0.775
DEN	459.43	21.39	31.13	54.11	1.00	459.43	106.63	4.31	MSP	0.612
JFK	523.90	72.79	41.25	85.01	0.77	523.90	199.05	2.63	JFK	0.611
PHX	134.23	8.45	21.29	26.88	0.69	134.23	56.62	2.37	BOS	0.587
LAS	177.81	8.80	13.95	29.54	0.92	177.81	52.29	3.40	PHX	0.550
EWR	328.13	65.64	34.36	56.57	0.68	328.13	156.57	2.10	STL	0.536
STL	100.95	4.39	14.85	24.47	0.81	100.95	43.72	2.31	LAX	0.503
MSP	104.31	9.04	4.18	26.34	0.87	104.31	39.55	2.64	EWR	0.486
BOS	215.26	6.33	28.19	50.53	1.00	215.26	85.05	2.53	RIC	0.435
RDU	32.33	3.10	0.40	6.18	1.00	32.33	9.68	3.34	SFO	0.431
ORF	15.48	1.20	3.07	5.14	0.51	15.48	9.41	1.65	ROA	0.416
RIC	18.44	0.77	2.90	6.16	0.77	18.44	9.83	1.88	MIA	0.396
ROA	5.23	0.50	0.86	1.55	0.46	5.23	2.92	1.79	ORF	0.382

Table 4.10.a shows the differences between (E) and (θ) for DMU LAX. The (E) method applied a reduction factor of 0.503 to all inputs. Reductions are determined by comparing each DMU to DEN only. In the (θ) method, inputs for LAX are reduced based on weights derived from a reference set made up of DEN and BOS. The output for LAX is optimized by determining what level of reduction is required for each input. Using the (E) method, one assumes that all the inputs are reduced evenly. Only one DMU, DEN is used to determine what that reduction is going to be. In the (θ) method, the complete population of DMUs become involved. Reductions in the inputs are determined by comparing each DMU against the entire population of DMUs. In Table 4.10.a, there is a large variation in the input projections. The variable x_2* is reduced by 55.4 percent, while x_1 and x_3 only by 3.63 percent by the (θ) method. This means that operation expenditures need to be reduced by 55.4 percent, and maintenance and staffing expenses by 3.63 percent in order to make LAX efficient. With the (E) method an optimal solution is not achieve.

Table 4.10.a
Projection Comparisons Between (E) and (θ) for LAX

Method	y_1*	x_1	x_2*	x_3	y'_1*	x'_1	x'_2*	x'_3
(E)	367.24	14.04	85.31	70.14	367.24	7.06	42.91	35.28
(θ)	367.24	14.04	85.31	70.14	367.24	13.53	38.03	67.58

POPULATION STUDY

Two populations of airports were defined in this thesis. The two populations are; top-ranking airports based on FAA enplanements rankings for a total of twelve (n_1), and four regional airports (n_2). The mixture of large and small airports caused a concern. This concern was based on the operational differences that may exist between the two populations of airports defined. The Wilcoxon rank sum test was used to test the hypothesis that the two populations are identical in their relative frequency distributions (Mendenhall and Sincich, 1995).

Wilcoxon Rank Sum Test ($n_1 \geq 10$ and $n_2 \geq 10$)
H_o : D_1 and D_2 are identical
H_a : D_1 is shifted either to the left or right of D_2
Where:
$D_1 \equiv$ relative frequency distribution of top ranking FAA enplanements (12 total)
$D_2 \equiv$ relative frequency distribution of regional airports (4 total)
$n_1 \equiv$ Population sample size of top ranking airports (12)
$n_2 \equiv$ Population sample size of regional airports (4)

Test statistic :

$$z = T_1 - \left[n_1 n_2 + n_1(n_1+1)/2\right] \Big/ \sqrt{n_1\, n_2(n_1 + n_2 + 1)/12} \qquad (9)$$

Rejection region : (two tailed)
$|z| > z_\alpha/2$

Equation (9) requires that each population have a sample size greater than or equal to ten. This rule of $n_1 \geq 10$ and $n_2 \geq 10$ is violated in this DEA analysis. An additional Wilcoxon rank sum test was performed below to compare to Equation (9).

Wilcoxon Rank Sum Test (random samples)
H_o : D_1 and D_2 are identical
H_a : D_1 is shifted either to the left or right of D_2
Where :
$D_1 \equiv$ relative frequency distribution of top ranking FAA enplanements (12 total)
$D_2 \equiv$ relative frequency distribution of regional airports (4 total)

Test statistic :

T_1, if $n_1 < n_2$

T_2, if $n_2 < n_1$ (10)

Rejection region :

$T \leq T_L$ or $T \geq T_U$

From Table 4.11, T_1 = 108.5 and T_2 = 27.5. Using Equation (9) the calculated value of z = .7882. Given α= 1.96, and a two tailed test, H_o should not be rejected, and the relative frequency distribution for population (n_1) and population (n_2) are identical. Using equation (10), T_2 = 27.5 is selected because of $n_2 < n_1$, corresponding to T_L = 16, and T_U=44 (Mendenhall and Sincich, 1995). Therefore H_o should not be rejected, and the relative frequency distribution for population (n_1) and population (n_2) are identical.

Table 4.11
Wilcoxon Rank Sum Test for Model AIRW06C
(DEA Determined Efficiencies)

ID	THETA	Rank (n1)	Rank (n2)	Total
ATL	1.000	14.5		14.5
DEN	1.000	14.5		14.5
BOS	1.000	14.5		14.5
RDU	1.000		14.5	14.5
LAX	0.964	12		12
LAS	0.918	11		11
MSP	0.874	10		10
STL	0.807	9		9
JFK	0.773	8		8
RIC	0.767		7	7
PHX	0.691	6		6
EWR	0.683	5		5
ORF	0.507		4	4
SFO	0.467	3		3
ROA	0.460		2	2
MIA	0.414	1		1
		108.5	27.5	**136**

The same Wilcoxon test was conducted on the populations ranked by standard efficiency measures, i.e., (E). These rankings are shown in Table 4.11.a. It was found that T_1 = 114 and T_2 = 22. Using Equation (9) the calculated value of z = 1.4552. Given α= 1.96, and a two tailed test, H_o should not be rejected, and the probability that a DMU from population (n_1) is chosen to be efficient is the same as one be chosen from population (n_2). Using equation (10), T_2 = 22 is selected because of $n_2 < n_1$,;

corresponding to $T_L = 16$, and T_U=44 (Mendenhall and Sincich, 1995). Therefore H_o should not be rejected, and the relative frequency distribution for population (n_1) and population (n_2) are identical.

The probability of determining an efficient DMU from the top ranked airports is the same as obtaining one from the regional airports. It was demonstrated that both the CCR and BCC model formulations selected DMUs from the smaller population of regional airports. Obtaining larger population samples and conducting the measures of efficiencies and the Wilcoxon rank sum test, may produce different results.

Table 4.11.a
Wilcoxon Rank Sum Test for Model AIRW06C
(Standard Determined Efficiencies)

ID	E	Rank (n1)	Rank (n2)	Total
DEN	1.000	16		16
LAS	0.789	15		15
ATL	0.781	14		14
RDU	0.775		13	13
MSP	0.612	12		12
JFK	0.611	11		11
BOS	0.587	10		10
PHX	0.550	9		9
STL	0.536	8		8
LAX	0.503	7		7
EWR	0.486	6		6
RIC	0.435		5	5
SFO	0.431	4		4
ROA	0.416		3	3
MIA	0.396	2		2
ORF	0.382		1	1
		114	22	**136**

CHAPTER V

RESULTS AND CONCLUSIONS

The objectives outlined in Chapter IV were all met. The use of DEA in determining airport efficiencies relative to defined daily operations is appropriate. Variations in the RTS, model orientation and evaluation provided a variety of results. Selecting which DEA model type to use was a major step, and can significantly change the results. Through a series of modeling trials and data conditioning, the DEA model AIRW06C is selected to be the best representation of daily airport operations. This model utilizes one output and three inputs and is selected for the following reasons:

- Proportionate increase to the inputs (x_1,x_2*,x_3), results in a proportionate increase to the output (y_1*),
- The reduction in outputs to one (y_1*), and three inputs (x_1,x_2*,x_3) represents daily monetary operations, and
- Output held constant, and the implementation of (ε).

The above points lead to the use of a CCR model and will be discussed in detail. The model characteristics and makeup can be found in Appendix K.

Proportionate increases to input, resulting in a proportionate increase to the output is a characteristic suited for the CCR model (Anderson, 1997). In Appendix J, scatter plots of the variables used in model AIRW06C are shown. From these scatter plots, it can be seen that there is correlation between the inputs and outputs. The output y_1* has correlation values of 0.793, 0.793, and 0.876 for the inputs x_1, x_2*, and x_3 respectively. These correlation values make the use of the CCR model appropriate. Had weak correlation existed between the data values, then the BCC model would have been better suited for this analysis.

During the analysis, various data products were used in an attempt to minimize the number of efficient DMUs. The process of selecting the data is discussed in detail in Chapters III and IV. The resulting selection of data defined daily monetary operations. The singular output y_1* is maximized in the objective function. To ensure every input is utilized during the optimization process, (ε) is employed. Without the use of (ε) some of the inputs may be removed, this may not be an acceptable action. For example if it is found that input x_3 (staffing expenditures) should not be used, this would not acceptable since staffing is required to operate the airport.

EFFICIENCY LEVELS

The approach and analysis discussed in Chapters III and IV, respectively lead to an in-depth utilization of DEA. Although model AIRW06C was chosen as the representative configuration to identify the efficient DMUs relative to daily operations, there is consistency in the DMUs that were found efficient across all the model variations listed in Appendix F. The CCR DEA model determined a total of four efficient DMUs, ATL, BOS, DEN, and RDU. The remaining twelve DMUs had efficiency ratings ranging from 0.4145 to 0.9636. The reference sets for these twelve inefficient DMUs were made up of the four efficient DMUs. All twelve inefficient DMUs utilized DEN within their reference set. BOS is used by eight DMUs and ATL and RDU by two DMUs. This suggest that DEN is the most influential in adjusting the inputs for the twelve inefficient DMUs, followed by BOS, and then ATL and RDU. Since the radial efficiency lines originate from the origin, all of the DMU's radial efficiency lines pass in the proximity of DEN. This can be seen in Figure 4.1.a, and explains why DEN is used in all the inefficient DMUs reference set.

The proportional reduction of (θ) may not by itself be sufficient in obtaining efficiency for the inefficient DMUs (Charnes, Cooper, Lewin and Seiford, 1994). This was demonstrated in the analysis, and as a result ninety-two percent of the inefficient DMUs have slack. In higher dimensional models (multiple outputs and or inputs), slack is usually required to reach the efficiency frontier. For a two-dimensional model, the slack is always zero. In Table 4.7, the various slack values for models AIRW06C, AIRW06D, and AIRW06V are provided. In DEA efficiency is defined by two conditions, first (θ) is equal to one, and second all slack is zero (Charnes, Cooper, Lewin and Seiford, 1994). In the model AIRW06C, SFO is the only DMU where the slack for all inputs is equal to zero, but the value of (θ) is not equal to one. The two phase approach to solving the DEA model is discussed in Chapter I. Recall that first (θ) is optimized without the use of slack, then slack is considered in the second phase. In order for a DMU to be efficient, θ must equal one and no slack exist. SFO is determined to be inefficient for these reasons. The remaining inefficient DMUs have slack in one or more inputs. The largest slack is for JFK, EWR, and LAX; their adjustment to the efficiency frontier is shown in Chapter IV.

The results of the DEA model AIRW06C have shown that for the given population sample of airports (n_p), there are only four efficient DMUs (airports) relative to the defined daily operations. Therefore the inefficient DMUs theoretically need to reduce their input(s) proportionally. Increasing the output for these inefficient DMUs may be an option. If this is done, then the DEA model should be rerun with the new output variables. Three of the four efficient DMUs were from the top ranked airports, and one from the regional. It was demonstrated that the probability of defining an efficient DMU from the top ranked airports is the same as defining one from the regional airports. Special attention was given to ensure that the data used in the analysis is appropriately scaled, accurate, and reliable.

The reduction and combining of data that was accomplished for this DEA model, was done so as to provide consistency between all the DMUs. There are a some important factors regarding the data selection, which lead to the selection of the modeling technique. These were defined in the beginning of this chapter. Appendix J shows a correlation analysis between the original output and inputs, and also the corresponding scatter plot matrices. In addition, steps were taken to ensure that data was not redundant; meaning that values were not being used in more than one input. The correlation between the original output and inputs was high. This implies that the data being used will provide reliable results utilizing a CCR DEA approach (Anderson, 1997). The scatter plots in Appendix J graphically show that there is a linear relationship relative to the output and inputs specified, and therefore suits this assumption.

Table 5.1 shows the necessary reduction for each input (x_1, x_2*, and x_3). These reductions would be necessary for the inefficient DMUs to achieve efficiency ratings of (θ=1). These reductions were determined by establishing ratios between the original inputs (x_1, x_2*, and x_3) and the projected inputs (x'_1, x'_2*, and x'_3). Since the model AIRW06C is input oriented, the output (y_1*) was held constant. Reductions multipliers in (x_1) range from 1.000 to 0.233, 1.000 to 0.398 for (x_2*), and 1.000 to 0.414 for (x_3). It is of interest to note that the reduction multiplier for all the inputs with respect to their DMU vary with one exception; SFO has the same multiplier for each input, this is due to the absence of any slack variables required to reach the efficiency frontier. This also holds true for the efficient DMUs ATL, BOS, DEN, and RDU. Recall that in order for a DMU to be found efficient, it must have a (θ) equal to one, and contain no slack. SFO has no slack, but it has a (θ) value of 0.4668. Table 5.1 also shows the same multipliers for two input variables within a DMU. For example the proportional reduction for x_{p1} and x_{p3} are the same for LAX. This indicates that those input variables do not have any slack. Table 4.7 shows the slack values, and can be correlated to Table 5.1 relative to multiplier repeatability.

Table 5.1
Required Reduction Multipliers for Inputs in Model AIRW06C

ID	x_{p1}	x_{p2}*	x_{p3}
ATL	1.000	1.000	1.000
DEN	1.000	1.000	1.000
BOS	1.000	1.000	1.000
RDU	1.000	1.000	1.000
LAX	0.964	0.446	0.964
LAS	0.917	0.918	0.756
MSP	0.874	0.873	0.638
STL	0.809	0.747	0.807
RIC	0.766	0.766	0.644
PHX	0.691	0.497	0.691
ORF	0.508	0.479	0.508
SFO	0.467	0.467	0.467
JFK	0.464	0.773	0.773
ROA	0.460	0.465	0.445
MIA	0.414	0.398	0.414
EWR	0.233	0.647	0.683

Figures 5.1.a through 5.1.c show the reductions for each input variable in their corresponding input category.

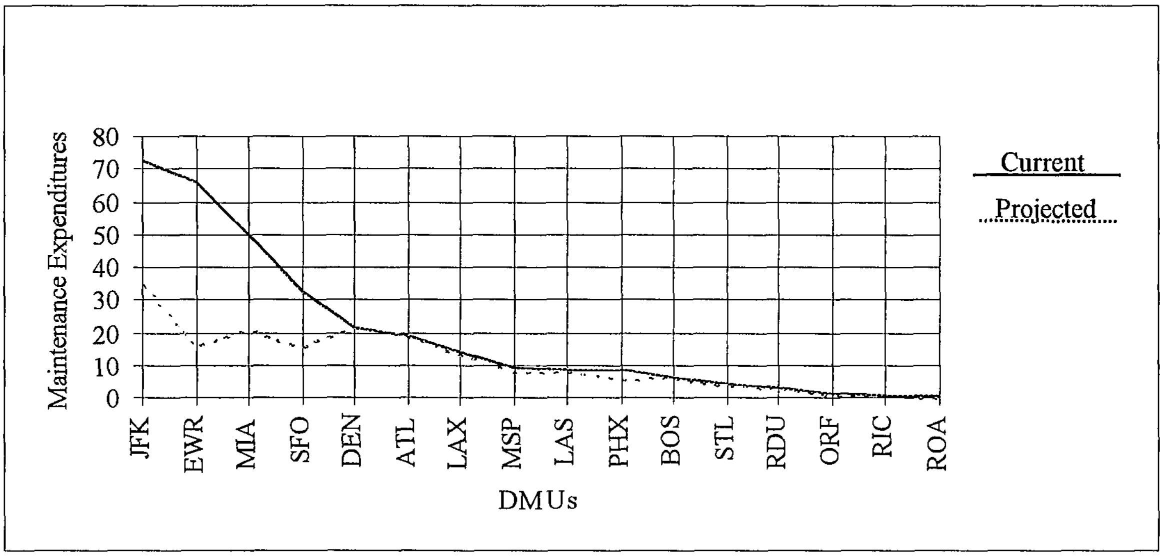

Figure 5.1.a. Required Maintenance Expenditure Reductions

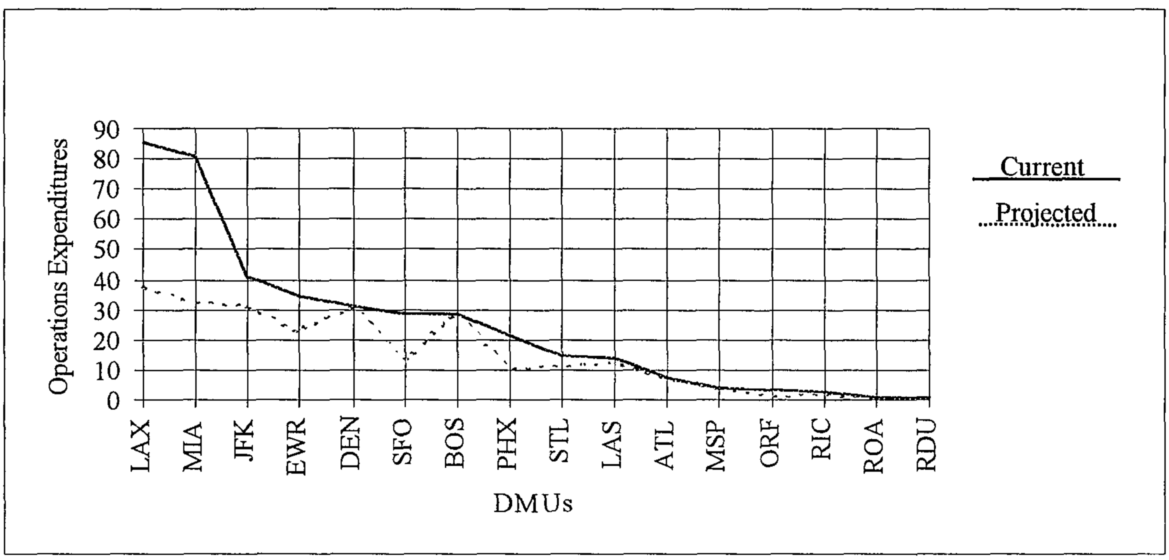

Figure 5.1.b. Required Operations Expenditure Reductions

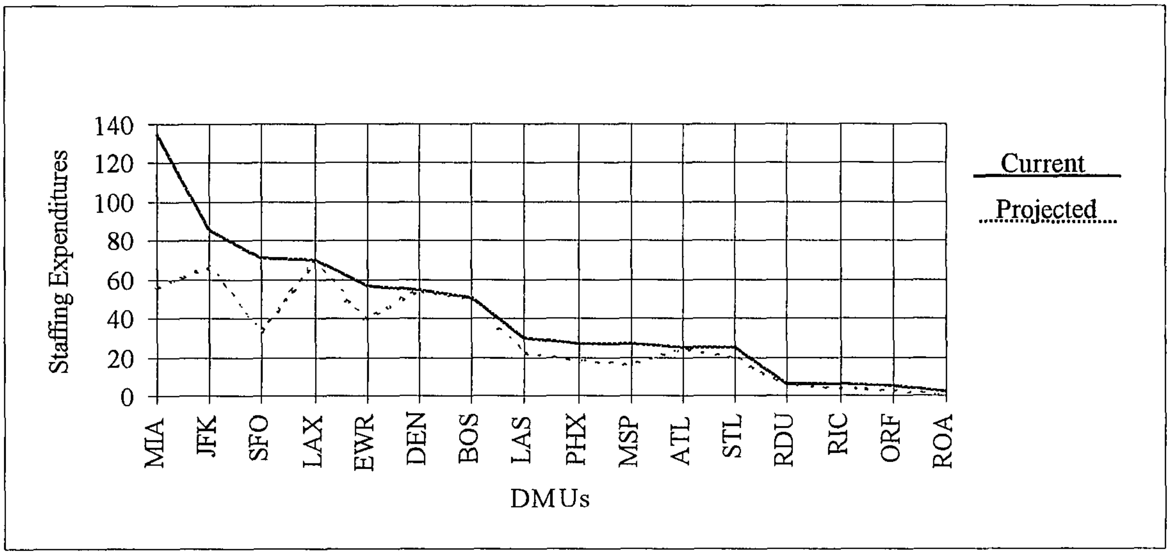

Figure 5.1.c. Required Staffing Expenditure Reductions

Figure 5.1.a shows that maintenance expenditures need to be reduced considerably for DMUs JFK, EWR, MIA, and SFO. This may not be possible, as it may be a result of outdated or aging systems or equipment. By upgrading or replacing such systems a cost savings may be provided in the long run. Comparisons to the other DMUs in this expenditure area may also provide insight to cost saving measures. Figure 5.1.b shows operational expenditures. The DMUs LAX, MIA, JFK, and SFO show the most need to try and reduce their operational expenditures. Looking into communication and utility cost may provide insight to ways in reducing these expenditures. Figure 5.1.c shows staffing expenditures. The DMUs MIA, JFK, SFO, and EWR require the most attention to reducing expenditures in this area. Looking into manning requirements should be a primary consideration. Possible implementation of automated systems in the areas of high personnel dependency may be a cost savings in the long run.

LIMITATIONS

The DEA modeling rules that were defined in Chapter IV, and their effects on DEA modeling, have been demonstrated. The initial DEA model had five outputs and four inputs. The basic rule of thumb relative to the number of DMUs being equal to three times or more the summation of outputs and inputs, allows DEA to define the efficient DMUs more accurately. In this case the total number of outputs and inputs was nine, and the number of DMUs was sixteen. To hold the number of outputs and inputs to nine, the number of DMUs should at a minimum be twenty-seven, preferable more. The results of this model provided a large number of efficient DMUs. After further evaluation, the outputs and inputs were selected so as to represent daily operations. The number of outputs and inputs was four, and therefore the minimum number of DMUs needed to be twelve. The use of (ε) was also incorporated to force a two-phase approach during the DEA modeling. This feature was automatically implemented with the use of IDEAS.

It would be preferred to have time series data on the airport operations in question, this data was not available, and therefore a snap shot in time was used. Since the FAA has now mandated that all FAA operated airports will be required to provide the type of data used in this study on a regular basis, adding a time domain approach to this DEA modeling would be very beneficial, and adjustments in data time lines may be incorporated.

POSSIBLE IMPROVEMENTS

At the time this study began there were a limited amount of data available on FAA sanctioned airports. Being able to use a larger population of DMUs would be an improvement to the analysis done to date. A larger population of DMUs would allow more comparative evaluations between the DMUs, and may generate additional efficient DMUs. Additional DMUs would allow more outputs and inputs to be added; this in turn will allow more precise identification of which variables within the model are responsible for making a DMU inefficient. Identification at a more precise level allows a manager to become more focused on potential improvements that can be made in operations. Additionally the incorporation of non-discretionary data may change the results of the DEA modeling. Incorporating information on activities that are not within the control of an airport manager (non-discretionary) will make the analysis more representative of daily operations. Modeling such factors as weather impacts, environmental regulations and others may enhance the fidelity of the DEA model.

CONCLUSION

The use of the CCR model provided insight to the problems with the inefficient DMUs. The BCC model was also utilized to compare the number of efficient DMUs found, to the number found in the CCR model. Although a large number of efficient DMUs were produced using the BCC model, there was consistency in which DMUs appeared as efficient in each modeling approach. Proportionally reducing the inputs as defined for each inefficient DMU may not be an easy task. Operationally defined parameters such as the number of employees required to operate a particular function due to safety or labor agreements with unions, may not be feasible to reduce. Appendix K provides detailed reports on the models AIRW06C, AIRW06D, and AIRW06V.

Chapter I discusses the importance of efficient airport operations to support the regional and national economy. With the globalization of today's economy, it is extremely important for airports to operate at peak efficiencies to assist in providing a stable economy. Improving airport efficiencies can be accomplished by proportional reductions in the defined inputs, increasing output while maintaining the current inputs, or a combination of the two. The key is that there is room for improvement, and DEA has been able to identify where that improvement can take place.

CHAPTER VI

FUTURE RESEARCH

During the development of this thesis, several areas of interest were generated. A total of twenty airports were initially selected for this DEA study. Out of those twenty, only sixteen were used due to the lack of data. Determining the number of efficient DMUs becomes dependent on several factors; for example the evaluation and modeling method, and data selection. Obtaining data on all FAA regulated and non regulated airports may be of interest. Building a DEA model for all these airports would require a significant amount of time, and require a DEA software package capable of handling a very large model. Determining which of the FAA regulated airports are efficient, and then looking at the regional economy that they service would allow parallels to be drawn between efficient airports and economic impacts, as well as differences between regulated and non-regulated airports. These parallels can be used to find not only potential improvement, but may assist in economic planning for the geographical region they service. In 1995 there were four-hundred and twenty-seven primary airports, and one-hundred and eighty-nine non-primary commercial airports. There are well over eighteen thousand all facilities airports in the United States. These range from heliports to seaplane facilities, and do not meet the FAA requirements for commercial air travel.

The use of discretionary and non-discretionary data in DEA models for airports should be investigated. Incorporation of non-discretionary data may enhance the realism of daily operations. Non-discretionary data causes the DEA model to optimize differently since this type of data is not controllable by the DMU, and therefore restricts allowable decisions. Examples of non-discretionary data is as follows:

- Operational limitations due to weather,
- Operational limitations due to environmental restrictions (noise, wildlife),
- Airport attributes (operational runways, terminals, etc.), and
- Airline operation correlation.

Obtaining data for all the airports over a period of a few years, and incorporation of a time domain into the DEA model may be studied. From this type of study, the use of regression techniques in the determination of economic stabilization actions relative to airport influences may be accomplished. This type of data can be used to help the FAA determine which airport will be financially subsidized, and to what level. Once a better understanding is obtained for the airports that operate within the continental United States, then comparisons against foreign airports can be performed. Looking at each country's airports and seeing how the world economy can be effected by inefficient airport operations may be used in the support of globilization of industries , technology, and trade.

Conducting a study as large as the global effects that airports have on the economy will require a wide variety of data variables to correctly model all the aspects of the various airport operations.

Variations in the way airports are used and governed may cause complications in forming a DEA model. This possible complication may be from a result of inconsistent data between each airport due to operational differences that exist within each country. This in turn may introduce data scaling problems. Techniques on handling this are available, but further work in this area needs to be conducted.

As indicated in Chapter IV all the inefficient DMUs used DEN in their reference set. Looking at the projected efficiency frontier shows that many DMUs tend to cluster in the vicinity of this airport. Implementing cluster analysis into a larger population may identify economic trends relative to specific groups of airports. Studying this possibly can lead to economic planning for regional areas that exhibit similar attributes such as airport operations, and their effect on jobs and their region's economy.

To summarize the above mentioned points, there are three areas that future research may be conducted relative to airport operating efficiencies. These are :

- Defining data selection and classification,
- Determining the best population size to use in an analysis to determining potential operational problems more accurately, and
- Determining the impacts that efficient airports have on regional, national and the global economy.

Data selection and classification (discretionary or non-discretionary) can provide a more realistic representation of an airport. The closer an organization or process is modeled, the better the possibility of determining specific operational problems. Airports are very complex systems with several activities being performed consecutively. Understanding the effects of using or not using certain data variables will provide additional assistance in problem solving.

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APPENDIX A

FAA FINANCIAL REPORTING FORMS

5100-125 AND 5200-126

OMB Number: 2120-0569

Financial Government Payment Report

Sponsor: ____________________

Name of Airport: ____________________

Fiscal Year Ended: ____________________

Payments to other government units

To unit of government ____________________

Payee - Department or Agency	Purpose	Amount
1	Law Enforcement	$ -
2	Firefighting	$ -
3	Legal Services	$ -
4	Engineering	$ -
5	Procurement	$ -
6		$ -
7		$ -
8		$ -
9		$ -
10		$ -
Subtotal		$ -

Payments to other government units

To unit of government ____________________

Payee - Department or Agency	Purpose	Amount
1		$ -
2		$ -
3		$ -
4		$ -
5		$ -
6		$ -
7		$ -
8		$ -
9		$ -
10		$ -
Subtotal		$ -

Services and property provided to other government units

To unit of government ____________________

Recipient - Department or Agency	Value
1	$ -
2	$ -
3	$ -
4	$ -
5	$ -
6	$ -
7	$ -
Subtotal	$ -

Compensation for property and services

From unit of government ____________________

Remitting Department or Agency	Compensation
1	$ -
2	$ -
3	$ -
4	$ -
5	$ -
6	$ -
7	$ -
Subtotal	$ -

Total of cash and investments held in airport accounts at the end of the fiscal year: $ -

In compliance with § 47107(a)(19) of Title 49 United States Code

Please complete this form noting fees and service provided to and received from other governments. Please list each government if more than one

I certify that the information on this form is true and accurate to the best of my knowledge and belief

____________________ Authorized Representative ____________ Date

____________________ Title

FAA Form 5100-126 (xx)

AGENCY DISPLAY OF ESTIMATED BURDEN.

The FAA estimates that the average burden for this report form is 3 hours per response. You may submit any comments concerning the accuracy of this burden estimate or any suggestions for reducing the burden to the Office of Management and Budget. You may also send comments to the Federal Aviation Administration, Program Support Branch, ARP-11, 800 Independence Avenue SW, Washington, DC 20591. Attention: OMB Number 2120-0557

Sponsor:
Name of Airport:
Fiscal Year Ended:

Operating and Financial Summary

Operating Revenue

Airline and other aeronautical revenue

1 Landing Fees	$ -	
2 Terminal/international arrival area rental or other charge	$ -	
3 Apron charges/tiedowns	$ -	
4 Fuel flowage fees	$ -	
5 Utilities	$ -	
6 FBO revenue contract or sponsor-operated	$ -	
7 Cargo and hangar rentals	$ -	
8 Securities Reimbursement	$ -	
9 Misc (Should not exceed 5% of total aeronautical)	$ -	
10 Other (Enter total here and add attachment)	$ -	
Total aeronautical revenue		$ -

Non-aeronautical

1. Rent/land rental	$ -	
2 Concessions	$ -	
3 Parking	$ -	
4 Rental Cars	$ -	
5 In-flight Catering	$ -	
6 Interest Income	$ -	
7 Royalties from natural resource sales	$ -	
8 Misc (Should not exceed 5% of total nonaeronautical)	$ -	
9 Other (Enter total here and add attachment)	$ -	
Total non-aeronautical revenue		$ -
Total Operating Revenue		$ -

Non-Operating Revenue and Other Receipts

Bond Proceeds	$ -	
Proceeds from sale of property not subject to Federal obligations	$ -	
Proceeds from sale of property subject to SPA/grant obligations	$ -	
Grant payments	$ -	
Passenger Facility Charges	$ -	
Other (Identify)	$ -	
Total Non-Operating Revenue/Other Receipts		$ -
Total Revenue and Other Receipts		$ -

Operating Expenses

1 Personnel Compensation and Benefits	$ -	
2. Communications and Utilities	$ -	
3 Supplies, Materials, Repairs, Maintenance	$ -	
4 Services (1)	$ -	
5 Insurance and Claims	$ -	
6 Government in lieu, permit, impact fees, etc	$ -	
7 Misc (Should not exceed 5% of total op expenses)	$ -	
8 Other (Enter total here and add attachment)	$ -	
Total Operating Expenditures		$ -
Debt Service Payments Net of Capitalized Interest		$ -
Transfers to Reserves		
1	$ -	
2	$ -	
Total Reserve Transfers		$ -
Non-Operating Capital Expenditures		
1	$ -	
2	$ -	
Total Capital Expenditures		$ -
Other Expenditures		
1	$ -	
2	$ -	
Total Other		$ -
Total Non-Operating Expenditures		$ -
Total Expenditures		$ -
REVENUE SURPLUS (LOSS)		$ -

Guidance used for accounting (check one or more) GAAP____ OMB Circular A-87 ____ Cash basis____ Accrual____ Other____

(1) Services includes fees for other governmental services not included in other categories

In compliance with section 47107(a) of the Title 49 United States Code and section 111(b) of the Federal Aviation Administration Authorization Act of 1994

Please complete this form in order assist the public in understanding airport finances and the use of airport generated revenue

I certify that the information on this form is true and accurate to the best of my knowledge and belief

Authorized Representative ____________ Date ____________

Title ____________

FAA Form 5100-125 (xx)

AGENCY DISPLAY OF ESTIMATED BURDEN.
The FAA estimates that the average burden for this report form is 5 hours per response You may submit any comments concerning the accuracy of this burden estimate or any suggestions for reducing the burden to the Office of Management and Budget You may also send comments to the Federal Aviation Administration, Program Support Branch, ARP-11, 800 Independence Avenue SW Washington, DC 20591, Attention OMB Number 2120-0557

APPENDIX B

FAA FINANCIAL DATA FILE

EXCEL® FORMAT

FAA Provided Data

	A	B	C	D
1	Rank	ARP ID Code	Airport Name	MGR_NAME
2	1	ORD	CHICAGO O'HARE INTL	HUGH MURPHY
3	2	ATL	WILLIAM B HARTSFIELD	ANGELA GITTENS
4	3	DFW	DALLAS/FORT WORTH INTERNATI	JEFFREY P. PEGON DIRECTOR
5	4	LAX	LOS ANGELES INTL	STEPHEN YEE
6	5	SFO	SAN FRANCISCO INTL	LOUIS TURPEN
7	6	MIA	MIAMI INTL	GARY J. DELLAPA
8	7	DEN	DENVER INTL	JAMES DE LONG
9	8	JFK	JOHN F KENNEDY INTL	ROBERT J. KELLY
10	9	DTW	DETROIT METRO WAYNE	ROBERT BRAUN
11	10	PHX	PHOENIX SKY HARBOR INTL	NEILSON A. BERTHOLF, JR. AAE
12	11	LAS	MC CARRAN INTL	ROBERT N BROADBENT,DIR.
13	12	EWR	NEWARK INTL	BENJAMIN DECOSTA
14	13	STL	LAMBERT-ST LOUIS INTL	LEONARD L. GRIGGS, JR.
15	14	MSP	MINNEAPOLIS-ST PAUL INTL	TIM ANDERSON
16	15	BOS	GENERAL EDWARD LAWRENCE LOGAN	THOMAS KINTON
17	50	RDU	RALEIGH-DURHAM INTL	JOHN C. BRANTLEY
18	73	ORF	NORFOLK INTL	WAYNE E. SHANK
19	82	RIC	RICHMOND INTL	DAVID L. BLACKSHEAR
20	134	ROA	ROANOKE REGIONAL	JACQUELINE L. SHUCK
21	168	PHF	NEWPORT NEWS	---

FAA Provided Data

	E	F	G	H	I
1	MGR_STREET	MGR_CTYSTZ	Report Due Date	Date Report Filed	Landing Fees
2	BOX 66142	CHICAGO IL 60666	4/30/97	DID NOT FILE	$0
3	HARTSFIELD ATL INTL AIRPORT	ATLANTA, GA 30320	4/30/97	5/1/97	$26,006,832
4	PO DRAWER DFW	DALLAS/FORT WORTH, TX 75261	1/28/97	DID NOT FILE	$0
5	1 WORLD WAY	LOS ANGELES, CA 90009	10/28/96	11/1/96	$97,010,000
6	SAN FRANCISCO ARPT COMM/SFIA	SAN FRANCISCO, CA 94128	10/28/96	8/27/96	$28,782,982
7	P.O. BOX 592075	MIAMI, FL 33159	1/28/97	4/16/97	$40,651,000
8	DEPT OF PUBLIC WORKS	DENVER, CO 80249	4/30/97	2/27/97	$86,562,044
9	BLDG 14	JAMAICA, NY 11430	4/30/97	4/29/97	$142,777,000
10	LEROY C SMITH TRML MEAZZANINE	DETROIT, MI 48242	3/30/97	DID NOT FILE	$0
11	3400 SKY HARBOR BLVD	PHOENIX, AZ 85034	10/28/96	11/21/96	$18,504,645
12	PO BOX 11005	LAS VEGAS, NV 89111	10/28/96	1/15/97	$22,426,000
13	TOWER ROAD, BUILDING #10	NEWARK, NJ 07114	4/30/97	4/29/97	$91,317,000
14	1320 MARKET ST	ST LOUIS, MO 63103	10/28/96	4/22/97	$30,738,685
15	4300 GLUMACK - RM 325	ST PAUL, MN 55111	4/30/97	3/12/97	$22,097,000
16	10 PARK PLAZA	BOSTON, MA 02116	10/28/96	10/29/96	$45,349,301
17	P.O. BOX 80001	RDU AIRPORT, NC 27623	7/29/96	8/30/96	$7,603,771
18	NORFOLK INTL AIRPORT	NORFOLK, VA 23518-5897	10/28/96	10/22/96	$1,294,159
19	BOX A-3	RICHMOND, VA 23231	10/28/96	1/15/97	$2,391,331
20	5202 AVIATION DRIVE	ROANOKE, VA 24012-1148	10/28/96	10/25/96	$944,371
21	---	---	DID NOT FILE	DID NOT FILE	$0

FAA Provided Data

	J	K	L	M	N	O
1	Terminal Area Rental	Apron Charges	Fuel Flowage Fees	Utilities	FBO Revenue	Cargo and Hangar Rental
2	$0	$0	$0	$0	$0	$0
3	$21,641,740	$4,041,601	$168,494	$0	$187,307	$12,050,010
4	$0	$0	$0	$0	$0	$0
5	$34,471,000	$2,293,000	$670,000	$1,734,000	$0	$8,023,000
6	$34,340,328	$47,915	$1,257,831	$11,859,167	$342,900	$15,074,826
7	$95,257,000	$3,450,000	$0	$0	$0	$0
8	$238,145,480	$0	$0	$0	$55,023	$3,535,292
9	$146,330,000	$0	$9,092,000	$43,199,000	$0	$79,766,000
10	$0	$0	$0	$0	$0	$0
11	$34,716,661	$115,912	$1,942,906	$0	$781,751	$1,543,112
12	$39,525,000	$5,215,000	$963,000	$0	$2,949,000	$0
13	$98,314,000	$0	$29,449,000	$7,179,000	$0	$19,201,000
14	$21,786,993	$263,998	$347,257	$1,175,347	$1,470,655	$1,911,448
15	$11,147,000	$4,242,000	$132,000	$1,264,000	$451,000	$13,690,000
16	$32,917,645	$2,618,193	$0	$11,502,609	$1,954,971	$12,534,675
17	$4,426,045	$0	$209,316	$278,159	$503,467	$1,201,924
18	$1,719,746	$1,357	$135,140	$151,387	$316,376	$179,565
19	$0	$609,560	$50,738	$152,443	$373,210	$203,034
20	$1,053,428	$218,259	$15,753	$0	$61,752	$232,902
21	$0	$0	$0	$0	$0	$0

FAA Provided Data

	P	Q	R	S	T
1	Securities Reimbursement	Misc Aeronautical Operating Rev	Other Aeronautical Operating Rev	Rent/Land Rental	Concessions
2	$0	$0	$0	$0	$0
3	$6,437,228	$0	$4,555,946	$15,115,860	$25,310,306
4	$0	$0	$0	$0	$0
5	$0	$1,171,000	$0	$27,911,000	$67,387,000
6	$1,934,240	$69,804	$494,455	$850,224	$43,996,299
7	$0	$0	$0	$83,583,000	$152,145,000
8	$989,337	$1,788,405	$13,552,077	$3,550,090	$11,848,566
9	$0	$0	$0	$4,347,000	$36,255,000
10	$0	$0	$0	$0	$0
11	$0	$74,739	$0	$13,483,099	$6,866,684
12	$0	$969,000	$0	$7,572,000	$37,228,000
13	$0	$0	$0	$301,000	$10,142,000
14	$0	$118,873	$0	$326,715	$8,906,159
15	$455,000	$154,000	$0	$2,216,000	$8,678,000
16	$906,241	$0	$0	$6,687,292	$15,025,657
17	$152,274	$7,099	$0	$70,831	$180,000
18	$124,083	$0	$0	$100,586	$5,082,556
19	$0	$0	$0	$4,302,004	$1,303,183
20	$0	$0	$0	$17,864	$209,110
21	$0	$0	$0	$0	$0

FAA Provided Data

	U	V	W	X	Y	Z
1	Parking	Rental Cars	In-flight Catering	Interest Income	Royalties from Natural Resources	Misc Non-Aeronautical Operating Rev
2	$0	$0	$0	$0	$0	$0
3	$44,354,041	$21,944,082	$0	$1,481,956	$205,156	$1,195,006
4	$0	$0	$0	$0	$0	$0
5	$48,743,000	$33,140,000	$110,000	$44,092,000	$0	$1,656,000
6	$50,374,686	$26,390,985	$0	$31,182,375	$0	$563
7	$25,518,000	$17,608,000	$0	$21,316,000	$0	$13,082,000
8	$47,118,216	$20,421,947	$834,566	$40,899,386	$842,199	$6,459,088
9	$26,205,000	$7,286,000	$23,299,000	$0	$0	$5,346,000
10	$0	$0	$0	$0	$0	$0
11	$24,710,017	$20,835,534	$0	$7,574,722	$0	$3,150,796
12	$7,582,000	$14,488,000	$1,929,000	$37,072,000	$0	$860,000
13	$46,009,000	$18,249,000	$5,754,000	$0	$0	$2,210,000
14	$10,875,070	$7,458,637	$885,702	$12,907,504	$0	$1,900,623
15	$30,291,000	$8,496,000	$386,000	$0	$320,000	$1,215,000
16	$55,891,668	$15,897,943	$0	$11,648,603	$0	$3,228,843
17	$9,553,759	$5,928,312	$577,889	$1,719,373	$0	$79,471
18	$5,578,889	$100,716	$208,688	$581,414	$0	$26,369
19	$4,670,770	$2,552,959	$156,052	$1,538,885	$0	$139,571
20	$1,171,404	$777,425	$0	$526,429	$0	$2,210
21	$0	$0	$0	$0	$0	$0

FAA Provided Data

	AA	AB	AC
1	Other Non-Aeronautical Opeating Rev	Bond Proceeds	Proceeds from Sale of Non-Obligated Property
2	$0	$0	$0
3	$2,893,446	$286,185,506	$499,990
4	$0	$0	$0
5	$4,753,000	$205,875,000	$0
6	$0	$615,841,772	$0
7	$0	$351,010,000	$0
8	$0	$525,801,152	$0
9	$12,204,000	$80,408,000	$10,811,000
10	$0	$0	$0
11	$0	$0	$0
12	$0	$402,750,000	$0
13	$19,144,000	$63,921,000	$5,155,000
14	$0	$0	$0
15	$0	$5,505,000	$418,000
16	$5,684,666	$51,000,000	$0
17	$505,034	$0	$0
18	$0	$0	$0
19	$0	$62,581,979	$0
20	$0	$0	$73,766
21	$0	$0	$0

FAA Provided Data

	AD	AE	AF	AG
1	Proceeds from Sale of Obligated Property	Grant Payments	Passenger Facility Charges	Other Non-Operating Revenue
2	$0	$0	$0	$0
3	$0	$13,000,095	$0	$27,376,282
4	$0	$0	$0	$0
5	$0	$6,020,000	$37,443,000	$0
6	$0	$11,623,205	$0	$0
7	$19,757,000	$38,202,000	$0	$0
8	$7,500,000	$39,661,670	$38,488,635	$360,350
9	$4,845,000	$0	$16,539,000	$43,989,000
10	$0	$0	$0	$0
11	$51,070	$17,233,352	$2,516,524	$1,651,951
12	$0	$6,813,000	$38,122,000	$8,491,000
13	$0	$10,223,000	$40,818,000	$7,245,000
14	$0	$13,047,704	$36,788,683	$0
15	$0	$36,025,000	$35,892,000	$45,282,000
16	$0	$16,063,757	$36,403,206	$0
17	$0	$4,571,089	$0	$50,000
18	$0	$6,036,981	$0	$176,918
19	$0	$8,945,878	$2,936,890	$3,398
20	$0	$2,491,590	$0	$264,640
21	$0	$0	$0	$0

FAA Provided Data

	AH	AI	AJ	AK
1	Personnel Compensation and Benefits	Communication and Utilities	Supplies, Materials, Repairs, Maintenance	Services
2	$0	$0	$0	$0
3	$25,081,729	$2,726,570	$18,891,744	$6,379,279
4	$0	$0	$0	$0
5	$70,136,000	$15,416,000	$14,040,000	$76,546,000
6	$70,700,898	$17,746,868	$32,580,416	$26,584,068
7	$135,067,000	$30,614,000	$49,896,000	$57,657,000
8	$54,105,270	$32,809,648	$21,392,883	$28,861,221
9	$85,011,000	$52,338,000	$72,788,000	$27,839,000
10	$0	$0	$0	$0
11	$26,883,258	$7,296,793	$8,454,687	$20,261,104
12	$29,541,000	$6,530,000	$8,800,000	$11,503,000
13	$56,572,000	$6,257,000	$65,638,000	$23,464,000
14	$24,466,710	$5,065,208	$4,393,796	$14,205,153
15	$26,341,000	$6,106,000	$9,035,000	$1,021,000
16	$50,532,103	$15,532,831	$6,326,810	$20,526,584
17	$6,177,519	$329,875	$3,102,336	$0
18	$5,143,299	$1,549,972	$1,195,928	$2,468,004
19	$6,161,252	$872,974	$774,355	$1,935,664
20	$1,554,256	$362,064	$504,660	$727,411
21	$0	$0	$0	$0

FAA Provided Data

	AL	AM	AN	AO	AP
1	Insurance and Claims	Government in Lieu, Permit, Impact Fees	Misc Operating Expenses	Other Operating Expense	Debt Service Payments
2	$0	$0	$0	$0	$0
3	$1,116,562	$139,128	$81,544	$3,890,436	$58,623,253
4	$0	$0	$0	$0	$0
5	$5,334,000	$0	$3,429,000	$11,417,000	$188,693,000
6	$932,907	$532,595	$962,204	$0	$63,323,850
7	$6,124,000	$0	$16,847,000	$15,515,000	$175,790,000
8	$1,540,753	$0	$726,233	$0	$274,589,945
9	$7,208,000	$1,003,000	$6,201,000	$66,953,000	$116,282,000
10	$0	$0	$0	$0	$0
11	$402,475	$1,833	$622,281	$0	$43,138,817
12	$1,505,000	$0	$942,000	$0	$87,875,000
13	$3,412,000	$1,680,000	$7,485,000	$35,264,000	$79,017,000
14	$599,723	$0	$50,000	$0	$38,389,872
15	$1,114,000	$0	$2,042,000	$7,870,000	$52,065,000
16	$1,464,311	$8,103,704	$6,200,070	$19,772,746	$30,962,000
17	$396,705	$1,000	$0	$0	$7,433,901
18	$313,091	$0	$286,176	$454,035	$3,250,000
19	$307,480	$0	$654,676	$0	$19,279,743
20	$129,157	$0	$3,469	$0	$815,440
21	$0	$0	$0	$0	$0

FAA Provided Data

	AQ	AR	AS
1	Total Reserves Transfers	Total Capital Expenditures	Other Non-Operating Expenditures
2	$0	$0	$0
3	$0	$143,767,720	$296,113,848
4	$0	$0	$0
5	$5,000,000	$57,118,000	$0
6	$4,000,000	$252,248,114	$0
7	$0	$269,124,000	$0
8	$28,448,670	$9,289,521	$508,350,000
9	$183,085,000	$111,001,000	$0
10	$0	$0	$0
11	$0	$35,961,815	$0
12	$69,973,000	$195,011,000	$22,178,000
13	$123,747,000	$93,983,000	$0
14	-$1,565,964	$32,513,217	$0
15	$0	$135,063,000	$27,703,000
16	$15,926,000	$106,275,000	$0
17	$0	$19,434,119	$0
18	$938,984	$5,878,139	$4,292,361
19	$128,857	$32,296,138	$8,066,401
20	$95,837	$2,493,535	$0
21	$0	$0	$0

APPENDIX C

FAA FINANCIAL DATA FILE

EXCEL® FORMAT

TOTALS

	A	B	C
25	Rank	ARP ID Code	Airport Name
26	1	ORD	CHICAGO O'HARE INTL
27	2	ATL	WILLIAM B HARTSFIELD
28	3	DFW	DALLAS/FORT WORTH INTERNATI
29	4	LAX	LOS ANGELES INTL
30	5	SFO	SAN FRANCISCO INTL
31	6	MIA	MIAMI INTL
32	7	DEN	DENVER INTL
33	8	JFK	JOHN F KENNEDY INTL
34	9	DTW	DETROIT METRO WAYNE
35	10	PHX	PHOENIX SKY HARBOR INTL
36	11	LAS	MC CARRAN INTL
37	12	EWR	NEWARK INTL
38	13	STL	LAMBERT-ST LOUIS INTL
39	14	MSP	MINNEAPOLIS-ST PAUL INTL
40	15	BOS	GENERAL EDWARD LAWRENCE LOGAN
41	50	RDU	RALEIGH-DURHAM INTL
42	73	ORF	NORFOLK INTL
43	82	RIC	RICHMOND INTL
44	134	ROA	ROANOKE REGIONAL
45	168	PHF	NEWPORT NEWS
46			TOTAL

	I	J	K	L	M	N	O	P
25	Total Aeronautical Revenue		Total Non-Aeronautical Revenue		Total Operating Revenue		Total Non-Operating Revenue/Other Receipts	
26	$0		$0		$0		$0	
27	$75,089,158		$112,499,853		$187,589,011		$327,061,873	
28	$0		$0		$0		$0	
29	$145,372,000		$227,792,000		$373,164,000		$249,338,000	
30	$94,204,448		$152,795,132		$246,999,580		$627,464,977	
31	$139,358,000		$313,252,000		$452,610,000		$408,969,000	
32	$344,627,658		$131,974,058		$476,601,716		$611,811,807	
33	$421,164,000		$114,942,000		$536,106,000		$156,592,000	
34	$0		$0		$0		$0	
35	$57,679,726		$76,620,852		$134,300,578		$21,452,897	
36	$72,047,000		$106,731,000		$178,778,000		$456,176,000	
37	$245,460,000		$101,809,000		$347,269,000		$127,362,000	
38	$57,813,256		$43,260,410		$101,073,666		$49,836,387	
39	$53,632,000		$51,602,000		$105,234,000		$123,122,000	
40	$107,783,635		$114,064,672		$221,848,307		$103,466,963	
41	$14,382,055		$18,614,669		$32,996,724		$4,621,089	
42	$3,921,813		$11,679,218		$15,601,031		$6,213,899	
43	$3,780,316		$14,663,424		$18,443,740		$74,468,145	
44	$2,526,465		$2,704,442		$5,230,907		$2,829,996	
45	$0		$0		$0		$0	
46	$1,838,841,530		$1,595,004,730		$3,433,846,260		$3,350,787,033	

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	Q	R	S	T	U	V	W	X
25	Total Revenue and Other Receipts		Total Operating Expenditures		Total Non-Operating Expenditures		Total Expenditures	
26	$0		$0		$0		$0	
27	$514,650,884		$58,306,992		$498,504,821		$556,811,813	
28	$0		$0		$0		$0	
29	$622,502,000		$196,318,000		$250,811,000		$447,129,000	
30	$874,464,557		$150,039,956		$319,571,964		$469,611,920	
31	$861,579,000		$311,720,000		$444,914,000		$756,634,000	
32	$1,088,413,523		$139,436,008		$820,678,136		$960,114,144	
33	$692,698,000		$319,341,000		$410,368,000		$729,709,000	
34	$0		$0		$0		$0	
35	$155,753,475		$63,922,431		$79,100,632		$143,023,063	
36	$634,954,000		$58,821,000		$375,037,000		$433,858,000	
37	$474,631,000		$199,772,000		$296,747,000		$496,519,000	
38	$150,910,053		$48,780,590		$69,337,125		$118,117,715	
39	$228,356,000		$53,529,000		$214,831,000		$268,360,000	
40	$325,315,270		$128,459,159		$153,163,000		$281,622,159	
41	$37,617,813		$10,007,435		$26,868,020		$36,875,455	
42	$21,814,930		$11,410,505		$14,359,484		$25,769,989	
43	$92,911,885		$10,706,401		$59,771,139		$70,477,540	
44	$8,060,903		$3,281,017		$3,404,812		$6,685,829	
45	$0		$0		$0		$0	
46	$6,784,633,293		$1,763,851,494		$4,037,467,133		$5,801,318,627	

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	Y
25	Revenue Surplus (Loss)
26	$0
27	($42,160,929)
28	$0
29	$175,373,000
30	$404,852,637
31	$104,945,000
32	$128,299,379
33	($37,011,000)
34	$0
35	$12,730,412
36	$201,096,000
37	($21,888,000)
38	$32,792,338
39	($40,004,000)
40	$43,693,111
41	$742,358
42	($3,955,059)
43	$22,434,345
44	$1,375,074
45	$0
46	$983,314,666

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APPENDIX D

DEA DATA FILE STRUCTURE

INPUT AND OUTPUT 1

DEA Models :
AIRPORT, AIRPORT1, AIRPORT2

[illegible]	[illegible]	Category	[illegible]	Units	No Variables
y1	u1	Total Operating Revenues (Aeronautical)	TORA	$	10
[illegible]	[illegible]	Total Operating Revenues (Non-Aeronaut	[illegible]	$	9
y2	u2	Total Non-operating Revenues	[illegible]	$	6
y3	u3	Total Number of Passenger Enplanements	[illegible]	No.	1

Defined		Make-up
[illegible] y1	1	Landing Fees
	2	Terminal/International arrival area rental or other charges
	3	Apron charges/tiedowns
	4	Fuel flowage fees
	5	Utilites
	6	FBO revenue: contract or sponsor-operated
	7	Cargo and hanger rentals
	8	Securites Reimbursement
	9	Misc
	10	Other
[illegible] y1	1	Rent/land rental
	2	Concessions
	3	Parking
	4	Rental cars
	5	In-flight catering
	6	Interest Income
	7	Royalties from natural resource sales
	8	Misc
	9	Other
y2 [illegible]	1	Bond Proceeds
	2	Proceeds from property sales subject to Federal obligations
	3	Proceeds from property sales subject to SPA obligations
	4	Grant payments
	5	Passenger facility charges
	6	Other
y3 [illegible]	1	Total number of passenger enplanements
Total	26	Number of Output variables

INPUT AND OUTPUT 1

Inputs	Weights	Category	Abbreviation	Units	No. Variables
x1	v1	Maintenance Expenditures	ME	$	1
x2	v2	Operations Expenditures	OE	$	6
x3	v3	Staffing Expenditures	SE	$	1

Defined		Make-up
x1	1	Supplies, Materials, Repairs, Maintenance
x2	1	Communications and Utilites
	2	Services
	3	Insurance and claims
	4	Government in lieu, permit, inpast fees, etc.
	5	Misc
	6	Other
x3	1	Personnel compensation and Benefits
Total	8	Number of Input variables

INPUT AND OUTPUT 2

DEA Models :
AIRPORT9

[illegible]	[illegible]	Category	[illegible]	Units	No Variables
y1	[illegible]	Total Operating Revenues (Aeronautical)	[illegible]	$	7
y2	[illegible]	Total Operating Revenues (Non-Aeronaut	[illegible]	$	7
y3	[illegible]	Total Non-operating Revenues	[illegible]	$	2
y4	[illegible]	Total Number of Passenger Enplanements	[illegible]	No	1
y5	[illegible]	Total tons of Cargo moved	[illegible]	[illegible]	1

Defined		Make-up
y1	1	Landing Fees
	2	Terminal/International arrival area rental or other charges
	3	Apron charges/tiedowns
	4	Fuel flowage fees
	5	Utilites
	6	FBO revenue: contract or sponsor-operated
	7	Cargo and hanger rentals
y2	1	Rent/land rental
	2	Concessions
	3	Parking
	4	Rental cars
	5	In-flight catering
	6	Interest Income
	8	Misc
y3	1	Bond Proceeds
	4	Grant payments
y4	1	Total number of passenger enplanements
y5	1	Total tons of Cargo moved
Total	18	Number of Output variables

INPUT AND OUTPUT 2

Inputs	Weights	Category	Abbreviation	Units	No. Variables
x1	v1	Maintenance Expenditures	ME	$	1
x2	v2	Operations Expenditures	OE	$	4
x3	v3	Staffing Expenditures	SE	$	1
x4	v4	Debt/Non-Operating Expenditures	DNOE	$	2

Defined		Make-up
x1	1	Supplies, Materials, Repairs, Maintenance
x2	1	Communications and Utilites
	2	Services
	3	Insurance and claims
	5	Misc
x3	1	Personnel compensation and Benefits
x4	1	Debt Service payments net of capitalized interest
	3	Total capial expenditures
Total	8	Number of Input variables

INPUT AND OUPUT 3

DEA Models :
AIRPORTA, AIRPORTB

		Category		Units	No Variables
[illegible]	[illegible]	Total Operating Revenues (Aeronautical)		$	7
[illegible]	[illegible]	Total Operating Revenues (Non-Aeronauti		$	7
[illegible]	[illegible]	Total Non-operating Revenues		$	2
y3	u3	Total Number of Passenger Enplanements	[illegible]	No	1
[illegible]	[illegible]	Total tons of Cargo moved		#	1

Defined		Make-up
[illegible]	1	Landing Fees
	2	Terminal/International arrival area rental or other charges
	3	Apron charges/tiedowns
	4	Fuel flowage fees
	5	Utilites
	6	FBO revenue: contract or sponsor-operated
	7	Cargo and hanger rentals
y1	1	Rent/land rental
	2	Concessions
	3	Parking
	4	Rental cars
	5	In-flight catering
	6	Interest Income
	8	Misc
y2	1	Bond Proceeds
	4	Grant payments
y3	1	Total number of passenger enplanements
y4	1	Total tons of Cargo moved
Total	18	Number of Output variables

INPUT AND OUPUT 3

Inputs	Weights	Category	Abbreviation	Units	No. Variables
x1	v1	Maintenance Expenditures	ME	$	1
x2	v2	Operations Expenditures	OE	$	4
x3	v3	Staffing Expenditures	SE	$	1
x4	v4	Debt/Non-Operating Expenditures	DNOE	$	2

Defined		Make-up
x1	1	Supplies, Materials, Repairs, Maintenance
x2	1	Communications and Utilites
	2	Services
	3	Insurance and claims
	5	Misc
x3	1	Personnel compensation and Benefits
x4	1	Debt Service payments net of capitalized interest
	3	Total capial expenditures
Total	8	Number of Input variables

Input and Output for DEA model

DEA Models :
AIRPORT3, AIRPORT4, AIRPORT5,AIRPORT6, AIRPORT7, AIRPORT8

Outputs	Weights	Category	[illegible]	Units	No Variables
y1	u1	Total Operating Revenues (Aeronautical)	[illegible]	$	10
y2	u2	Total Operating Revenues (Non-Aeronaut	[illegible]	$	9
y3	u3	Total Non-operating Revenues	[illegible]	$	6
y4	u4	Total Number of Passenger Enplanements	[illegible]	No	1
y5	u5	Total tons of Cargo moved	[illegible]	#	1

Defined		Make-up
y1	1	Landing Fees
	2	Terminal/International arrival area rental or other charges
	3	Apron charges/tiedowns
	4	Fuel flowage fees
	5	Utilites
	6	FBO revenue: contract or sponsor-operated
	7	Cargo and hanger rentals
	8	Securites Reimbursement
	9	Misc
	10	Other
y2	1	Rent/land rental
	2	Concessions
	3	Parking
	4	Rental cars
	5	In-flight catering
	6	Interest Income
	7	Royalties from natural resource sales
	8	Misc
	9	Other
y3	1	Bond Proceeds
	2	Proceeds from property sales subject to Federal obligations
	3	Proceeds from property sales subject to SPA obligations
	4	Grant payments
	5	Passenger facility charges
	6	Other
y4	1	Total number of passenger enplanements
y5	1	Total tons of Cargo moved
Total	27	Number of Output variables

Input and Output for DEA model

Inputs	Weights	Category	Abbreviation	Units	No. Variables
x1	v1	Maintenance Expenditures	ME	$	1
x2	v2	Operations Expenditures	OE	$	6
x3	v3	Staffing Expenditures	SE	$	1
x4	v4	Debt/Non-Operating Expenditures	DNOE	$	4

Defined		Make-up
x1	1	Supplies, Materials, Repairs, Maintenance
x2	1	Communications and Utilites
	2	Services
	3	Insurance and claims
	4	Government in lieu, permit, inpast fees, etc.
	5	Misc
	6	Other
x3	1	Personnel compensation and Benefits
x4	1	Debt Service payments net of capitalized interest
	2	Total reserve transfers
	3	Total capial expenditures
	4	Total other
Total	12	Number of Input variables

APPENDIX E

IDEAS DATA FILE

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Data base File : AIRPORT.DBF

AIRPORTID	OUTPUT1	OUTPUT2	OUTPUT3	INPUT1
ATL	187.589011	327.061873	28.090978	18.891744
BOS	221.848307	103.466963	11.734693	6.326810
DEN	476.601716	611.811807	14.858763	21.392883
EWR	347.269000	127.362000	13.230961	65.638000
JFK	536.106000	156.592000	14.601827	72.788000
LAS	178.778000	456.176000	13.243748	8.800000
LAX	373.164000	249.338000	26.133795	14.040000
MIA	452.610000	408.969000	16.065673	49.896000
MSP	105.234000	123.122000	12.559491	9.035000
ORF	15.601031	6.213899	1.335378	1.195928
PHX	134.300578	21.452897	13.738433	8.454687
RDU	32.996724	4.621089	2.938831	3.102336
RIC	18.443740	74.468145	1.066411	0.774355
ROA	5.230907	2.829996	0.323145	0.504660
SFO	246.999580	627.464977	17.187766	32.580416
STL	101.073666	49.836387	12.790701	4.393796

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Data base File : AIRPORT.DBF

AIRPORTID	INPUT2	INPUT3
ATL	14.333519	25.081729
BOS	71.600246	50.532103
DEN	63.937855	54.105270
EWR	77.562000	56.572000
JFK	161.542000	85.011000
LAS	20.480000	29.541000
LAX	112.142000	70.136000
MIA	126.757000	135.067000
MSP	18.153000	26.341000
ORF	5.071278	5.143299
PHX	28.584486	26.883258
RDU	0.727580	6.177519
RIC	3.770794	6.161252
ROA	1.222101	1.554256
SFO	46.758642	70.700898
STL	19.920084	24.466710

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Data base File : AIRPORT1.DBF

AIRPORTID	OUTPUT1	OUTPUT2	OUTPUT3	INPUT1
ATL	187.589011	327.061873	28.090978	18.891744
BOS	221.848307	103.466963	11.734693	6.326810
DEN	476.601716	611.811807	14.858763	21.392883
EWR	347.269000	127.362000	13.230961	65.638000
JFK	536.106000	156.592000	14.601827	72.788000
LAS	178.778000	456.176000	13.243748	8.800000
LAX	373.164000	249.338000	26.133795	14.040000
MIA	452.610000	408.969000	16.065673	49.896000
MSP	105.234000	123.122000	12.559491	9.035000
PHX	134.300578	21.452897	13.738433	8.454687
SFO	246.999580	627.464977	17.187766	32.580416
STL	101.073666	49.836387	12.790701	4.393796

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Data base File : AIRPORT1.DBF

AIRPORTID	INPUT2	INPUT3
ATL	14.333519	25.081729
BOS	71.600246	50.532103
DEN	63.937855	54.105270
EWR	77.562000	56.572000
JFK	161.542000	85.011000
LAS	20.480000	29.541000
LAX	112.142000	70.136000
MIA	126.757000	135.067000
MSP	18.153000	26.341000
PHX	28.584486	26.883258
SFO	46.758642	70.700898
STL	19.920084	24.466710

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Data base File : AIRPORT2.DBF

AIRPORTID	OUTPUT1	OUTPUT2	OUTPUT3	INPUT1
ORF	15.601031	6.213899	1.335378	1.195928
RDU	32.996724	4.621089	2.938831	3.102336
RIC	18.443740	74.468145	1.066411	0.774355
ROA	5.230907	2.829996	0.323145	0.504660

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Data base File : AIRPORT2.DBF

AIRPORTID	INPUT2	INPUT3
ORF	5.071278	5.143299
RDU	0.727580	6.177519
RIC	3.770794	6.161252
ROA	1.222101	1.554256

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Data base File : AIRPORT3.DBF

ID	OUTPUT1	OUTPUT2	OUTPUT3	OUTPUT4
ATL	75.089158	112.499853	327.061873	28.090978
BOS	107.783635	114.064672	103.466963	11.734693
DEN	344.627658	131.974058	611.811807	14.858763
EWR	245.460000	101.809000	127.362000	13.230961
JFK	421.164000	114.942000	156.592000	14.601827
LAS	72.047000	106.731000	456.176000	13.243748
LAX	145.372000	227.792000	249.338000	26.133795
MIA	139.358000	313.252000	408.969000	16.065673
MSP	53.632000	51.602000	123.122000	12.559491
ORF	3.921813	11.679218	6.213899	1.335378
PHX	57.679726	76.620852	21.452897	13.738433
RDU	14.382055	18.614669	4.621089	2.938831
RIC	3.780316	14.663424	74.468145	1.066411
ROA	2.526465	2.704442	2.829996	0.323145
SFO	94.204448	152.795132	627.464977	17.187766
STL	57.813256	43.260410	49.836387	12.790701

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Data base File : AIRPORT3.DBF

ID	OUTPUT5	INPUT1	INPUT2	INPUT3
ATL	0.771390	18.891744	14.333519	25.081729
BOS	0.394474	6.326810	71.600246	50.532103
DEN	0.376179	21.392883	63.937855	54.105270
EWR	0.942666	65.638000	77.562000	56.572000
JFK	1.584332	72.788000	161.542000	85.011000
LAS	0.050769	8.800000	20.480000	29.541000
LAX	1.597222	14.040000	112.142000	70.136000
MIA	1.584683	49.896000	126.757000	135.067000
MSP	0.364946	9.035000	18.153000	26.341000
ORF	0.025669	1.195928	5.071278	5.143299
PHX	0.260006	8.454687	28.584486	26.883258
RDU	0.098308	3.102336	0.727580	6.177519
RIC	0.064439	0.774355	3.770794	6.161252
ROA	0.022618	0.504660	1.222101	1.554256
SFO	0.696233	32.580416	46.758642	70.700898
STL	0.127566	4.393796	19.920084	24.466710

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Data base File : AIRPORT3.DBF

ID	INPUT4
ATL	498.504821
BOS	153.163000
DEN	820.678136
EWR	296.747000
JFK	410.368000
LAS	375.037000
LAX	250.811000
MIA	444.914000
MSP	214.831000
ORF	14.359484
PHX	79.100632
RDU	26.868020
RIC	59.771139
ROA	3.404812
SFO	319.571964
STL	69.337125

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Data base File : AIRPORT4.DBF

ID	OUTPUT1	OUTPUT2	OUTPUT3	OUTPUT4
ATL	75.089158	112.499853	327.061873	28.090978
BOS	107.783635	114.064672	103.466963	11.734693
DEN	344.627658	131.974058	611.811807	14.858763
EWR	245.460000	101.809000	127.362000	13.230961
JFK	421.164000	114.942000	156.592000	14.601827
LAS	72.047000	106.731000	456.176000	13.243748
LAX	145.372000	227.792000	249.338000	26.133795
MIA	139.358000	313.252000	408.969000	16.065673
MSP	53.632000	51.602000	123.122000	12.559491
PHX	57.679726	76.620852	21.452897	13.738433
SFO	94.204448	152.795132	627.464977	17.187766
STL	57.813256	43.260410	49.836387	12.790701

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Data base File : AIRPORT4.DBF

ID	OUTPUT5	INPUT1	INPUT2	INPUT3
ATL	0.771390	18.891744	14.333519	25.081729
BOS	0.394474	6.326810	71.600246	50.532103
DEN	0.376179	21.392883	63.937855	54.105270
EWR	0.942666	65.638000	77.562000	56.572000
JFK	1.584332	72.788000	161.542000	85.011000
LAS	0.050769	8.800000	20.480000	29.541000
LAX	1.597222	14.040000	112.142000	70.136000
MIA	1.584683	49.896000	126.757000	135.067000
MSP	0.364946	9.035000	18.153000	26.341000
PHX	0.260006	8.454687	28.584486	26.883258
SFO	0.696233	32.580416	46.758642	70.700898
STL	0.127566	4.393796	19.920084	24.466710

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Data base File : AIRPORT4.DBF

ID	INPUT4
ATL	498.504821
BOS	153.163000
DEN	820.678136
EWR	296.747000
JFK	410.368000
LAS	375.037000
LAX	250.811000
MIA	444.914000
MSP	214.831000
PHX	79.100632
SFO	319.571964
STL	69.337125

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Data base File : AIRPORT5.DBF

ID	OUTPUT1	OUTPUT2	OUTPUT3	OUTPUT4
ORF	3.921813	11.679218	6.213899	1.335378
RDU	14.382055	18.614669	4.621089	2.938831
RIC	3.780316	14.663424	74.468145	1.066411
ROA	2.526465	2.704442	2.829996	0.323145

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Data base File : AIRPORT5.DBF

ID	OUTPUT5	INPUT1	INPUT2	INPUT3
ORF	0.025669	1.195928	5.071278	5.143299
RDU	0.098308	3.102336	0.727580	6.177519
RIC	0.064439	0.774355	3.770794	6.161252
ROA	0.022618	0.504660	1.222101	1.554256

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Data base File : AIRPORT5.DBF

ID	INPUT4
ORF	14.359484
RDU	26.868020
RIC	59.771139
ROA	3.404812

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Data base File : AIRPORT6.DBF

ID	OUTPUT1	OUTPUT2	OUTPUT3	OUTPUT4
ATL	187.589011	327.061873	28.090978	0.771390
BOS	221.848307	103.466963	11.734693	0.394474
DEN	476.601716	611.811807	14.858763	0.376179
EWR	347.269000	127.362000	13.230961	0.942666
JFK	536.106000	156.592000	14.601827	1.584332
LAS	178.778000	456.176000	13.243748	0.050769
LAX	373.164000	249.338000	26.133795	1.597222
MIA	452.610000	408.969000	16.065673	1.584683
MSP	105.234000	123.122000	12.559491	0.364946
ORF	15.601031	6.213899	1.335378	0.025669
PHX	134.300578	21.452897	13.738433	0.260006
RDU	32.996724	4.621089	2.938831	0.098308
RIC	18.443740	74.468145	1.066411	0.064439
ROA	5.230907	2.829996	0.323145	0.022618
SFO	246.999580	627.464977	17.187766	0.696233
STL	101.073666	49.836387	12.790701	0.127566

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Data base File : AIRPORT6.DBF

ID	INPUT1	INPUT2	INPUT3	INPUT4
ATL	18.891744	14.333519	25.081729	498.504821
BOS	6.326810	71.600246	50.532103	153.163000
DEN	21.392883	63.937855	54.105270	820.678136
EWR	65.638000	77.562000	56.572000	296.747000
JFK	72.788000	161.542000	85.011000	410.368000
LAS	8.800000	20.480000	29.541000	375.037000
LAX	14.040000	112.142000	70.136000	250.811000
MIA	49.896000	126.757000	135.067000	444.914000
MSP	9.035000	18.153000	26.341000	214.831000
ORF	1.195928	5.071278	5.143299	14.359484
PHX	8.454687	28.584486	26.883258	79.100632
RDU	3.102336	0.727580	6.177519	26.868020
RIC	0.774355	3.770794	6.161252	59.771139
ROA	0.504660	1.222101	1.554256	3.404812
SFO	32.580416	46.758642	70.700898	319.571964
STL	4.393796	19.920084	24.466710	69.337125

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Data base File : AIRPORT7.DBF

ID	OUTPUT1	OUTPUT2	OUTPUT3	OUTPUT4
ATL	187.589011	327.061873	28.090978	0.771390
BOS	221.848307	103.466963	11.734693	0.394474
DEN	476.601716	611.811807	14.858763	0.376179
EWR	347.269000	127.362000	13.230961	0.942666
JFK	536.106000	156.592000	14.601827	1.584332
LAS	178.778000	456.176000	13.243748	0.050769
LAX	373.164000	249.338000	26.133795	1.597222
MIA	452.610000	408.969000	16.065673	1.584683
MSP	105.234000	123.122000	12.559491	0.364946
PHX	134.300578	21.452897	13.738433	0.260006
SFO	246.999580	627.464977	17.187766	0.696233
STL	101.073666	49.836387	12.790701	0.127566

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Data base File : AIRPORT7.DBF

ID	INPUT1	INPUT2	INPUT3	INPUT4
ATL	18.891744	14.333519	25.081729	498.504821
BOS	6.326810	71.600246	50.532103	153.163000
DEN	21.392883	63.937855	54.105270	820.678136
EWR	65.638000	77.562000	56.572000	296.747000
JFK	72.788000	161.542000	85.011000	410.368000
LAS	8.800000	20.480000	29.541000	375.037000
LAX	14.040000	112.142000	70.136000	250.811000
MIA	49.896000	126.757000	135.067000	444.914000
MSP	9.035000	18.153000	26.341000	214.831000
PHX	8.454687	28.584486	26.883258	79.100632
SFO	32.580416	46.758642	70.700898	319.571964
STL	4.393796	19.920084	24.466710	69.337125

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Data base File : AIRPORT8.DBF

ID	OUTPUT1	OUTPUT2	OUTPUT3	OUTPUT4
ORF	15.601031	6.213899	1.335378	0.025669
RDU	32.996724	4.621089	2.938831	0.098308
RIC	18.443740	74.468145	1.066411	0.064439
ROA	5.230907	2.829996	0.323145	0.022618

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Data base File : AIRPORT8.DBF

ID	INPUT1	INPUT2	INPUT3	INPUT4
ORF	1.195928	5.071278	5.143299	14.359484
RDU	3.102336	0.727580	6.177519	26.868020
RIC	0.774355	3.770794	6.161252	59.771139
ROA	0.504660	1.222101	1.554256	3.404812

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Data base File : AIRPORT9.DBF

ID	OUTPUT1	OUTPUT2	OUTPUT3	OUTPUT4
ATL	64.095984	109.401251	299.185601	28.090978
BOS	106.877394	108.380006	67.063757	11.734693
DEN	328.297839	131.131859	565.462822	14.858763
EWR	245.460000	82.665000	74.144000	13.230961
JFK	421.164000	102.738000	80.408000	14.601827
LAS	71.078000	106.731000	409.563000	13.243748
LAX	144.201000	223.039000	211.895000	26.133795
MIA	139.358000	313.252000	389.212000	16.065673
MSP	53.023000	51.282000	41.530000	12.559491
ORF	3.797730	11.679218	6.036981	1.335378
PHX	57.604987	76.620852	17.233352	13.738433
RDU	14.222682	18.109635	4.571089	2.938831
RIC	3.780316	14.663424	71.527857	1.066411
ROA	2.526465	2.704442	2.491590	0.323145
SFO	91.705949	152.795132	627.464977	17.187766
STL	57.694383	43.260410	13.047704	12.790701

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Data base File : AIRPORT9.DBF

ID	OUTPUT5	INPUT1	INPUT2	INPUT3
ATL	0.771390	18.891744	7.577385	25.081729
BOS	0.394474	6.326810	28.190965	50.532103
DEN	0.376179	21.392883	31.128207	54.105270
EWR	0.942666	65.638000	34.361000	56.572000
JFK	1.584332	72.788000	41.248000	85.011000
LAS	0.050769	8.800000	13.950000	29.541000
LAX	1.597222	14.040000	85.309000	70.136000
MIA	1.584683	49.896000	80.628000	135.067000
MSP	0.364946	9.035000	4.177000	26.341000
ORF	0.025669	1.195928	3.067271	5.143299
PHX	0.260006	8.454687	21.285860	26.883258
RDU	0.098308	3.102336	0.396705	6.177519
RIC	0.064439	0.774355	2.897820	6.161252
ROA	0.022618	0.504660	0.860037	1.554256
SFO	0.696233	32.580416	28.479179	70.700898
STL	0.127566	4.393796	14.854876	24.466710

Data base File : AIRPORT9.DBF

ID	INPUT4
ATL	202.390973
BOS	137.237000
DEN	283.879466
EWR	173.000000
JFK	227.283000
LAS	282.886000
LAX	245.811000
MIA	444.914000
MSP	187.128000
ORF	9.128139
PHX	79.100632
RDU	26.868020
RIC	51.575881
ROA	3.308975
SFO	315.571964
STL	70.903089

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Data base File : AIRPORTA.DBF

ID	OUTPUT1	OUTPUT2	OUTPUT3	OUTPUT4
ATL	173.497235	299.185601	28.090978	0.771390
BOS	215.257400	67.063757	11.734693	0.394474
DEN	459.429698	565.462822	14.858763	0.376179
EWR	328.125000	74.144000	13.230961	0.942666
JFK	523.902000	80.408000	14.601827	1.584332
LAS	177.809000	409.563000	13.243748	0.050769
LAX	367.240000	211.895000	26.133795	1.597222
MIA	452.610000	389.212000	16.065673	1.584683
MSP	104.305000	41.530000	12.559491	0.364946
ORF	15.476948	6.036981	1.335378	0.025669
PHX	134.225839	17.233352	13.738433	0.260006
RDU	32.332317	4.571089	2.938831	0.098308
RIC	18.443740	71.527857	1.066411	0.064439
ROA	5.230907	2.491590	0.323145	0.022618
SFO	244.501081	627.464977	17.187766	0.696233
STL	100.954793	13.047704	12.790701	0.127566

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Data base File : AIRPORTA.DBF

ID	INPUT1	INPUT2	INPUT3	INPUT4
ATL	18.891744	7.577385	25.081729	202.390973
BOS	6.326810	28.190965	50.532103	137.237000
DEN	21.392883	31.128207	54.105270	283.879466
EWR	65.638000	34.361000	56.572000	173.000000
JFK	72.788000	41.248000	85.011000	227.283000
LAS	8.800000	13.950000	29.541000	282.886000
LAX	14.040000	85.309000	70.136000	245.811000
MIA	49.896000	80.628000	135.067000	444.914000
MSP	9.035000	4.177000	26.341000	187.128000
ORF	1.195928	3.067271	5.143299	9.128139
PHX	8.454687	21.285860	26.883258	79.100632
RDU	3.102336	0.396705	6.177519	26.868020
RIC	0.774355	2.897820	6.161252	51.575881
ROA	0.504660	0.860037	1.554256	3.308975
SFO	32.580416	28.479179	70.700898	315.571964
STL	4.393796	14.854876	24.466710	70.903089

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Data base File : AIRPORTB.DBF

ID	OUTPUT1	OUTPUT2	OUTPUT3	OUTPUT4
ATL	173.497235	299.185601	28.090978	0.771390
BOS	215.257400	67.063757	11.734693	0.394474
DEN	459.429698	565.462822	14.858763	0.376179
EWR	328.125000	74.144000	13.230961	0.942666
JFK	523.902000	80.408000	14.601827	1.584332
LAS	177.809000	409.563000	13.243748	0.050769
LAX	367.240000	211.895000	26.133795	1.597222
MIA	452.610000	389.212000	16.065673	1.584683
MSP	104.305000	41.530000	12.559491	0.364946
PHX	134.225839	17.233352	13.738433	0.260006
SFO	244.501081	627.464977	17.187766	0.696233
STL	100.954793	13.047704	12.790701	0.127566

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Data base File : AIRPORTB.DBF

ID	INPUT1	INPUT2	INPUT3	INPUT4
ATL	18.891744	7.577385	25.081729	202.390973
BOS	6.326810	28.190965	50.532103	137.237000
DEN	21.392883	31.128207	54.105270	283.879466
EWR	65.638000	34.361000	56.572000	173.000000
JFK	72.788000	41.248000	85.011000	227.283000
LAS	8.800000	13.950000	29.541000	282.886000
LAX	14.040000	85.309000	70.136000	245.811000
MIA	49.896000	80.628000	135.067000	444.914000
MSP	9.035000	4.177000	26.341000	187.128000
PHX	8.454687	21.285860	26.883258	79.100632
SFO	32.580416	28.479179	70.700898	315.571964
STL	4.393796	14.854876	24.466710	70.903089

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Data base File : AIRPORTZ.DBF

ID	OUTPUT1	OUTPUT2	OUTPUT3	OUTPUT4
ATL	173.497235	299.185601	28.090978	0.771390
BOS	215.257400	67.063757	11.734693	0.394474
DEN	459.429698	565.462822	14.858763	0.376179
EWR	328.125000	74.144000	13.230961	0.942666
JFK	523.902000	80.408000	14.601827	1.584332
LAS	177.809000	409.563000	13.243748	0.050769
LAX	367.240000	211.895000	26.133795	1.597222
MIA	452.610000	389.212000	16.065673	1.584683
MSP	104.305000	41.530000	12.559491	0.364946
ORF	15.476948	6.036981	1.335378	0.025669
PHX	134.225839	17.233352	13.738433	0.260006
RDU	32.332317	4.571089	2.938831	0.098308
RIC	18.443740	71.527857	1.066411	0.064439
ROA	5.230907	2.491590	0.323145	0.022618
SFO	244.501081	627.464977	17.187766	0.696233
STL	100.954793	13.047704	12.790701	0.127566

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Data base File : AIRPORTZ.DBF

ID	INPUT1	INPUT2	INPUT3	INPUT4
ATL	18.891744	7.577385	25.081729	202.390973
BOS	6.326810	28.190965	50.532103	137.237000
DEN	21.392883	31.128207	54.105270	283.879466
EWR	65.638000	34.361000	56.572000	173.000000
JFK	72.788000	41.248000	85.011000	227.283000
LAS	8.800000	13.950000	29.541000	282.886000
LAX	14.040000	85.309000	70.136000	245.811000
MIA	49.896000	80.628000	135.067000	444.914000
MSP	9.035000	4.177000	26.341000	187.128000
ORF	1.195928	3.067271	5.143299	9.128139
PHX	8.454687	21.285860	26.883258	79.100632
RDU	3.102336	0.396705	6.177519	26.868020
RIC	0.774355	2.897820	6.161252	51.575881
ROA	0.504660	0.860037	1.554256	3.308975
SFO	32.580416	28.479179	70.700898	315.571964
STL	4.393796	14.854876	24.466710	70.903089

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Data base File : AIRPORTZ.DBF

ID	INPUT5
ATL	0.900000
BOS	0.700000
DEN	0.700000
EWR	0.700000
JFK	0.750000
LAS	0.800000
LAX	1.000000
MIA	0.800000
MSP	0.600000
ORF	0.900000
PHX	0.950000
RDU	0.800000
RIC	0.900000
ROA	0.900000
SFO	0.800000
STL	0.800000

APPENDIX F

DEA MODEL LOG

10/28/97 *DATA FILE.DOC*

Data files :

AIRPORT	=	ALL 16 DMUs	3O/3I	AIRPORT2	=	4 DMUs	3O/3I
AIRPORT1	=	12 DMUs	3O/3I	AIRPORT4	=	12 DMUs	5O/4I
AIRPORT3	=	ALL 16 DMUs	5O/4I	AIRPORT6	=	16 DMUs	4O/4I
AIRPORT5	=	4 DMUs	5O/4I			(Combined y1 and y2)	
AIRPORT7	=	12 DMUs	40/4I	AIRPORT8	=	4 DMUs	4O/4I
		(Combined y1 and y2)				(Combined y1 and y2)	
AIRPORT9	=	16 DMUs	50/4I	AIRPORTA	=	16 DMUs	4O/4I
		(Condensed)				(Condensed)	
AIRPORTZ	=	AIRPORTA + Theoretical		AIRPORTB	=	12 DMUs	4O/4I
		Weather percentages				(Combined y1 and y2)	

Models :

MODEL	DMUs	O/I	FORM	ORIEN	EVAL	DATA FILE	No. of $\theta = 1$	REMARKS
AIR	16	3/3	CRS	O	INV	AIRPORT	8	
AIR1	12	3/3	CRS	O	INV	AIRPORT1	6	
AIR2	4	3/3	CRS	O	INV	AIRPORT2	3	
AIR3	16	2/3	CRS	O	INV	AIRPORT	6	No enplanements
AIR4	12	2/3	CRS	O	INV	AIRPORT1	4	No enplanements
AIR5	4	2/3	CRS	O	INV	AIRPORT2	2	No enplanements
AIR6	16	3/3	CRS	I	INV	AIRPORT	8	
AIR7	12	3/3	CRS	I	INV	AIRPORT1	6	
AIR8	4	3/3	CRS	I	INV	AIRPORT2	3	
AIR9	16	2/3	CRS	I	INV	AIRPORT	6	No enplanements
AIR10	12	2/3	CRS	I	INV	AIRPORT1	4	No enplanements
AIR11	4	2/3	CRS	I	INV	AIRPORT2	2	No enplanements
AIRV	16	3/3	VRS	O	INV	AIRPORT	11	
AIRV1	12	3/3	VRS	O	INV	AIRPORT1	8	
AIRV2	4	3/3	VRS	O	INV	AIRPORT2	4	
AIRV3	16	2/3	VRS	O	INV	AIRPORT	10	No enplanements

AIRV4	12	2/3	VRS	O	INV	AIRPORT1	8	No enplanements
AIRV5	4	2/3	VRS	O	INV	AIRPORT2	3	No enplanements
AIRV6	16	3/3	VRS	I	INV	AIRPORT	11	
AIRV7	12	3/3	VRS	I	INV	AIRPORT1	8	
AIRV8	4	3/3	VRS	I	INV	AIRPORT2	4	
AIRV9	16	2/3	VRS	I	INV	AIRPORT	10	No enplanements
AIRV10	12	2/3	VRS	I	INV	AIRPORT1	8	No enplanements
AIRV11	4	2/3	VRS	I	INV	AIRPORT2	3	No enplanements
AIR16I	16	3/3	CRS	I	INV ARCH	AIRPORT	8	
AIR16	16	3/3	CRS	I	STD ARCH	AIRPORT	8	
AIR12	12	3/3	CRS	I	STD ARCH	AIRPORT1	6	
AIR04	4	3/3	CRS	I	STD ARCH	AIRPORT2	3	
AIR162	16	2/3	CRS	I	STD ARCH	AIRPORT	6	
AIR122	12	2/3	CRS	I	STD ARCH	AIRPORT1	4	
AIR042	4	2/3	CRS	I	STD ARCH	AIRPORT2	2	
AIRX	16	5/4	CRS	I	INV ARCH	AIRPORT3	13	

MODEL	DMUs	O/I	FORM	ORIEN	EVAL	DATA FILE	No. of $\theta = 1$	REMARKS
AIR16X	16	5/4	CRS	I	STD ARCH	AIRPORT3	13	
AIR12X	12	5/4	CRS	I	STD ARCH	AIRPORT3	10	
AIR4X	4	5/4	CRS	I	STD ARCH	AIRPORT3	4	
AIRV16	16	3/3	VRS	I	INV ARCH	AIRPORT	11	
AIR16XR	16	5/4	CRS	I	STD ARCH	AIRPORT3	11	
AIR001	16	4/4	CRS	I	STD ARCH	AIRPORT3	12	Minus y3
AIR002	16	3/4	CRS	I	STD ARCH	AIRPORT3	11	Minus y3, y5
AIR003	16	2/4	CRS	I	STD ARCH	AIRPORT3	11	Minus y3,y5,y4
AIR004	16	4/3	CRS	I	STD ARCH	AIRPORT3	7	Operations Center Minus y3, x4
AIR005	12	4/3	CRS	I	STD ARCH	AIRPORT3	11	Operations Center Minus y3, x4
AIR006	16	4/4	CRS	I	STD ARCH	AIRPORT6	12	
AIR007	16	¾	CRS	I	STD ARCH	AIRPORT6	11	Minus y3 (Which is y2 in data file, since y1 and y2 are combined)
AIR008	16	3/3	CRS	I	STD ARCH	AIRPORT6	8	Minus y2 and x4
AIR009	12	3/3	CRS	I	STD ARCH	AIRPORT7	6	Minus y2 and x4
AIR010	4	3/3	CRS	I	STD ARCH	AIRPORT8	4	Minus y2 and x4
AIR011	16	2/3	CRS	I	STD ARCH	AIRPORT6	7	Minus y2, y4, x4
AIRM01	16	5/4	CRS	I	STD ARCH	AIRPORT9	14	CONDENSED
AIRM02	16	4/4	CRS	I	STD ARCH	AIRPORTA	14	COMBINED. (y1 and y2 added)
AIRM03	16	¾	CRS	I	STD ARCH	AIRPORTA	12	Minus y2 (was y3)
AIRM04	16	3/3	CRS	I	STD ARCH	AIRPORTA	9	Minus y2, x4
AIRM05	16	2/3	CRS	I	STD ARCH	AIRPORTA	8	Minus y2, y5 and x4

MODEL	DMUs	O/I	FORM	ORIEN	EVAL	DATA FILE	No. of θ = 1	REMARKS	INFO
AIRW01	16	2/2	CRS	I	STD ARCH	AIRPORT3	5	Minus y3, y4, y5	Minus x3, x4
AIRW02	12	2/2	CRS	I	STD ARCH	AIRPORT4	5	Minus y3, y4, y5	Minus x3, x4
AIRW03	4	2/2	CRS	I	STD ARCH	AIRPORT5	3	Minus y3, y4, y5	Minus x3, x4
AIRW04	16	1/3	CRS	I	STD ARCH	AIRPORT6	5	Minus y2, y3, y4	Minus x4
AIRW05	16	2/3	CRS	I	STD ARCH	AIRPORT6	7	Minus y2, y3	Minus x4
AIRW06	16	2/3	CRS	I	STD ARCH	AIRPORT3	7	Minus y3, y4, y5	Minus x4
AIRW06A	16	1/3	CRS	I	STD ARCH	AIRPORT6	5	Minus y2, y3, y4	Minus x4
AIRW06B	16	2/3	CRS	I	STD ARCH	AIRPORT9	7	Minus y3, y4, y5	Minus x4
AIRW06C	16	1/3	CRS	I	STD ARCH	AIRPORTA	4	Minus y2, y3, y4	Minus x4
AIRW06D	12	1/3	CRS	I	STD ARCH	AIRPORTB	4	Minus y2, y3, y4	Minus x4
AIRW06E	16	2/3	CRS	I	STD ARCH	AIRPORTA	8	Minus y2, y4	Minus x4
AIRZ01	16	¼	CRS	I	STD ARCH	AIRPORTZ	6	Minus y2, y3, y4	Minus x4
AIRW06CR	16	1/3 N/NND	CRS	I	STD ARCH	AIRPORTA	4	Minus y2, y3, y4	Minus x4
AIR9R	16	2/3 NN/NND	CRS	I	STD ARCH	AIRPORT	6		
AIR01A	16	2/4 DD/DDDN	CRS	I	STD ARCH	AIRPORT9	7		Cargo moved to input
AIR01B	16	3/3 DDD/DDN	CRS	I	STD ARCH	AIRPORT9	8		
AIR01C	16	2/3 DD/DDN	CRS	I	STD ARCH	AIRPORT9	7		
AIRXX1	16	5/4 DDDNN/DDDN	CRS	I	STD ARCH	AIRPORT3	13		
AIRXX2	16	¼ D/DDDN	CRS	I	STD ARCH	AIRPORTA	5		
AIRXX3	16	2/4 DD/DDDN	CRS	I	STD ARCH	AIRPORTA	10		
AIRXX4	16	2/4 DD/DDDN	CRS	I	STD ARCH	AIRPORT9	10		
AIRW06V	16	1/3	VRS	I	STD ARCH	AIRPORTA	9		
AIR16X1	16	4/4	CRS	I	STD ARCH	AIRPORT3	13		
AIRW06C	16	1/3	VRS	I	STD ARCH	AIRPORTA	9		

AIRW06C	16	1/3	CRS	O	STD ARCH	AIRPORTA	4		
AIRW06C	16	1/3	VRS	O	STD ARCH	AIRPORTA	9		
AIRW06CR	16	1/3	VRS	I	STD ARCH	AIRPORT	9		

APPENDIX G

IDEAS DATA FILE, RAW FORM

Airport.asc

```
'ATL                    '          187.58901100        327.06187300        18.89174400
      14.33351900            25.08172900  1
'LAX                    '          373.16400000        249.33800000        14.04000000
     112.14200000            70.13600000  1
'SFO                    '          246.99958000        627.46497700        32.58041600
      46.75864200            70.70089800  1
'MIA                    '          452.61000000        408.96900000        49.89600000
     126.75700000           135.06700000  1
'DEN                    '          476.60171600        611.81180700        21.39288300
      63.93785500            54.10527000  1
'JFK                    '          536.10600000        156.59200000        72.78800000
     161.54200000            85.01100000  1
'PHX                    '          134.30057800         21.45289700         8.45468700
      28.58448600            26.88325800  1
'LAS                    '          178.77800000        456.17600000         8.80000000
      20.48000000            29.54100000  1
'EWR                    '          347.26900000        127.36200000        65.63800000
      77.56200000            56.57200000  1
'STL                    '          101.07366600         49.83638700         4.39379600
      19.92008400            24.46671000  1
'MSP                    '          105.23400000        123.12200000         9.03500000
      18.15300000            26.34100000  1
'BOS                    '          221.84830700        103.46696300         6.32681000
      71.60024600            50.53210300  1
'RDU                    '           32.99672400          4.62108900         3.10233600
       0.72758000             6.17751900  1
'ORF                    '           15.60103100          6.21389900         1.19592800
       5.07127800             5.14329900  1
'RIC                    '           18.44374000         74.46814500         0.77435500
       3.77079400             6.16125200  1
'ROA                    '            5.23090700          2.82999600         0.50466000
       1.22210100             1.55425600  1
```

Airport1.asc

```
'ATL                      '         187.58901100        327.06187300        18.89174400
     14.33351900          25.08172900  1
'LAX                      '         373.16400000        249.33800000        14.04000000
    112.14200000          70.13600000  1
'SFO                      '         246.99958000        627.46497700        32.58041600
     46.75864200          70.70089800  1
'MIA                      '         452.61000000        408.96900000        49.89600000
    126.75700000         135.06700000  1
'DEN                      '         476.60171600        611.81180700        21.39288300
     63.93785500          54.10527000  1
'JFK                      '         536.10600000        156.59200000        72.78800000
    161.54200000          85.01100000  1
'PHX                      '         134.30057800         21.45289700         8.45468700
     28.58448600          26.88325800  1
'LAS                      '         178.77800000        456.17600000         8.80000000
     20.48000000          29.54100000  1
'EWR                      '         347.26900000        127.36200000        65.63800000
     77.56200000          56.57200000  1
'STL                      '         101.07366600         49.83638700         4.39379600
     19.92008400          24.46671000  1
'MSP                      '         105.23400000        123.12200000         9.03500000
     18.15300000          26.34100000  1
'BOS                      '         221.84830700        103.46696300         6.32681000
     71.60024600          50.53210300  1
```

Airport2.asc

```
'RDU                    '          32.99672400          4.62108900           3.10233600
       0.72758000            6.17751900  1
'ORF                    '          15.60103100          6.21389900           1.19592800
       5.07127800            5.14329900  1
'RIC                    '          18.44374000         74.46814500           0.77435500
       3.77079400            6.16125200  1
'ROA                    '           5.23090700          2.82999600           0.50466000
       1.22210100            1.55425600  1
```

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'ATL                '          75.08915800        112.49985300        327.06187300
     28.09097800         0.77139000         18.89174400         14.33351900        25
.08172900         498.50482100  1
'LAX                '         145.37200000        227.79200000        249.33800000
     26.13379500         1.59722200         14.04000000        112.14200000        70
.13600000         250.81100000  1
'SFO                '          94.20444800        152.79513200        627.46497700
     17.18776600         0.69623300         32.58041600         46.75864200        70
.70089800         319.57196400  1
'MIA                '         139.35800000        313.25200000        408.96900000
     16.06567300         1.58468300         49.89600000        126.75700000       135
.06700000         444.91400000  1
'DEN                '         344.62765800        131.97405800        611.81180700
     14.85876300         0.37617900         21.39288300         63.93785500        54
.10527000         820.67813600  1
'JFK                '         421.16400000        114.94200000        156.59200000
     14.60182700         1.58433200         72.78800000        161.54200000        85
.01100000         410.36800000  1
'PHX                '          57.67972600         76.62085200         21.45289700
     13.73843300         0.26000600          8.45468700         28.58448600        26
.88325800          79.10063200  1
'LAS                '          72.04700000        106.73100000        456.17600000
     13.24374800         0.05076900          8.80000000         20.48000000        29
.54100000         375.03700000  1
'EWR                '         245.46000000        101.80900000        127.36200000
     13.23096100         0.94266600         65.63800000         77.56200000        56
.57200000         296.74700000  1
'STL                '          57.81325600         43.26041000         49.83638700
     12.79070100         0.12756600          4.39379600         19.92008400        24
.46671000          69.33712500  1
'MSP                '          53.63200000         51.60200000        123.12200000
     12.55949100         0.36494600          9.03500000         18.15300000        26
.34100000         214.83100000  1
'BOS                '         107.78363500        114.06467200        103.46696300
     11.73469300         0.39447400          6.32681000         71.60024600        50
.53210300         153.16300000  1
'RDU                '          14.38205500         18.61466900          4.62108900
```

Airport3.asc

```
     2.93883100           0.09830800           3.10233600           0.72758000           6
.17751900         26.86802000  1
'ORF                 '          3.92181300           11.67921800           6.21389900
     1.33537800           0.02566900           1.19592800           5.07127800           5
.14329900         14.35948400  1
'RIC                 '          3.78031600           14.66342400           74.46814500
     1.06641100           0.06443900           0.77435500           3.77079400           6
.16125200         59.77113900  1
'ROA                 '          2.52646500            2.70444200            2.82999600
     0.32314500           0.02261800           0.50466000           1.22210100           1
.55425600          3.40481200  1
```

Airport4.asc

```
'ATL                          '            75.08915800         112.49985300          18.89174400
     14.33351900  1
'LAX                          '           145.37200000         227.79200000          14.04000000
    112.14200000  1
'SFO                          '            94.20444800         152.79513200          32.58041600
     46.75864200  1
'MIA                          '           139.35800000         313.25200000          49.89600000
    126.75700000  1
'DEN                          '           344.62765800         131.97405800          21.39288300
     63.93785500  1
'JFK                          '           421.16400000         114.94200000          72.78800000
    161.54200000  1
'PHX                          '            57.67972600          76.62085200           8.45468700
     28.58448600  1
'LAS                          '            72.04700000         106.73100000           8.80000000
     20.48000000  1
'EWR                          '           245.46000000         101.80900000          65.63800000
     77.56200000  1
'STL                          '            57.81325600          43.26041000           4.39379600
     19.92008400  1
'MSP                          '            53.63200000          51.60200000           9.03500000
     18.15300000  1
'BOS                          '           107.78363500         114.06467200           6.32681000
     71.60024600  1
```

Airport5.asc

```
'RDU                         '          14.38205500          18.61466900          3.10233600
      0.72758000  1
'ORF                         '           3.92181300          11.67921800          1.19592800
      5.07127800  1
'RIC                         '           3.78031600          14.66342400          0.77435500
      3.77079400  1
'ROA                         '           2.52646500           2.70444200          0.50466000
      1.22210100  1
```

Airport6.asc

```
'ATL                           '          187.58901100         18.89174400         14.33351900
     25.08172900  1
'LAX                           '          373.16400000         14.04000000        112.14200000
     70.13600000  1
'SFO                           '          246.99958000         32.58041600         46.75864200
     70.70089800  1
'MIA                           '          452.61000000         49.89600000        126.75700000
    135.06700000  1
'DEN                           '          476.60171600         21.39288300         63.93785500
     54.10527000  1
'JFK                           '          536.10600000         72.78800000        161.54200000
     85.01100000  1
'PHX                           '          134.30057800          8.45468700         28.58448600
     26.88325800  1
'LAS                           '          178.77800000          8.80000000         20.48000000
     29.54100000  1
'EWR                           '          347.26900000         65.63800000         77.56200000
     56.57200000  1
'STL                           '          101.07366600          4.39379600         19.92008400
     24.46671000  1
'MSP                           '          105.23400000          9.03500000         18.15300000
     26.34100000  1
'BOS                           '          221.84830700          6.32681000         71.60024600
     50.53210300  1
'RDU                           '           32.99672400          3.10233600          0.72758000
      6.17751900  1
'ORF                           '           15.60103100          1.19592800          5.07127800
      5.14329900  1
'RIC                           '           18.44374000          0.77435500          3.77079400
      6.16125200  1
'ROA                           '            5.23090700          0.50466000          1.22210100
      1.55425600  1
```

Airport7.asc

```
'ATL                     '         187.58901100         28.09097800            0.77139000
     18.89174400          14.33351900          25.08172900  1
'LAX                     '         373.16400000         26.13379500            1.59722200
     14.04000000         112.14200000          70.13600000  1
'SFO                     '         246.99958000         17.18776600            0.69623300
     32.58041600          46.75864200          70.70089800  1
'MIA                     '         452.61000000         16.06567300            1.58468300
     49.89600000         126.75700000         135.06700000  1
'DEN                     '         476.60171600         14.85876300            0.37617900
     21.39288300          63.93785500          54.10527000  1
'JFK                     '         536.10600000         14.60182700            1.58433200
     72.78800000         161.54200000          85.01100000  1
'PHX                     '         134.30057800         13.73843300            0.26000600
      8.45468700          28.58448600          26.88325800  1
'LAS                     '         178.77800000         13.24374800            0.05076900
      8.80000000          20.48000000          29.54100000  1
'EWR                     '         347.26900000         13.23096100            0.94266600
     65.63800000          77.56200000          56.57200000  1
'STL                     '         101.07366600         12.79070100            0.12756600
      4.39379600          19.92008400          24.46671000  1
'MSP                     '         105.23400000         12.55949100            0.36494600
      9.03500000          18.15300000          26.34100000  1
'BOS                     '         221.84830700         11.73469300            0.39447400
      6.32681000          71.60024600          50.53210300  1
```

Airport8.asc

```
'RDU                  '         32.99672400         2.93883100          0.09830800
      3.10233600           0.72758000           6.17751900  1
'ORF                  '         15.60103100         1.33537800          0.02566900
      1.19592800           5.07127800           5.14329900  1
'RIC                  '         18.44374000         1.06641100          0.06443900
      0.77435500           3.77079400           6.16125200  1
'ROA                  '          5.23090700         0.32314500          0.02261800
      0.50466000           1.22210100           1.55425600  1
```

Airport9.asc

```
'ATL                    '         64.09598400       109.40125100          18.89174400
      7.57738500          25.08172900       202.39097300  1
'LAX                    '        144.20100000       223.03900000          14.04000000
     85.30900000          70.13600000       245.81100000  1
'SFO                    '         91.70594900       152.79513200          32.58041600
     28.47917900          70.70089800       315.57196400  1
'MIA                    '        139.35800000       313.25200000          49.89600000
     80.62800000         135.06700000       444.91400000  1
'DEN                    '        328.29783900       131.13185900          21.39288300
     31.12820700          54.10527000       283.87946600  1
'JFK                    '        421.16400000       102.73800000          72.78800000
     41.24800000          85.01100000       227.28300000  1
'PHX                    '         57.60498700        76.62085200           8.45468700
     21.28586000          26.88325800        79.10063200  1
'LAS                    '         71.07800000       106.73100000           8.80000000
     13.95000000          29.54100000       282.88600000  1
'EWR                    '        245.46000000        82.66500000          65.63800000
     34.36100000          56.57200000       173.00000000  1
'STL                    '         57.69438300        43.26041000           4.39379600
     14.85487600          24.46671000        70.90308900  1
'MSP                    '         53.02300000        51.28200000           9.03500000
      4.17700000          26.34100000       187.12800000  1
'BOS                    '        106.87739400       108.38000600           6.32681000
     28.19096500          50.53210300       137.23700000  1
'RDU                    '         14.22268200        18.10963500           3.10233600
      0.39670500           6.17751900        26.86802000  1
'ORF                    '          3.79773000        11.67921800           1.19592800
      3.06727100           5.14329900         9.12813900  1
'RIC                    '          3.78031600        14.66342400           0.77435500
      2.89782000           6.16125200        51.57588100  1
'ROA                    '          2.52646500         2.70444200           0.50466000
      0.86003700           1.55425600         3.30897500  1
```

Airporta.asc

```
'ATL                    '           173.49723500        18.89174400         7.57738500
    25.08172900  1
'LAX                    '           367.24000000        14.04000000        85.30900000
    70.13600000  1
'SFO                    '           244.50108100        32.58041600        28.47917900
    70.70089800  1
'MIA                    '           452.61000000        49.89600000        80.62800000
   135.06700000  1
'DEN                    '           459.42969800        21.39288300        31.12820700
    54.10527000  1
'JFK                    '           523.90200000        72.78800000        41.24800000
    85.01100000  1
'PHX                    '           134.22583900         8.45468700        21.28586000
    26.88325800  1
'LAS                    '           177.80900000         8.80000000        13.95000000
    29.54100000  1
'EWR                    '           328.12500000        65.63800000        34.36100000
    56.57200000  1
'STL                    '           100.95479300         4.39379600        14.85487600
    24.46671000  1
'MSP                    '           104.30500000         9.03500000         4.17700000
    26.34100000  1
'BOS                    '           215.25740000         6.32681000        28.19096500
    50.53210300  1
'RDU                    '            32.33231700         3.10233600         0.39670500
     6.17751900  1
'ORF                    '            15.47694800         1.19592800         3.06727100
     5.14329900  1
'RIC                    '            18.44374000         0.77435500         2.89782000
     6.16125200  1
'ROA                    '             5.23090700         0.50466000         0.86003700
     1.55425600  1
```

Airportb.asc

```
'ATL                          '          173.49723500        18.89174400         7.57738500
     25.08172900  1
'LAX                          '          367.24000000        14.04000000        85.30900000
     70.13600000  1
'SFO                          '          244.50108100        32.58041600        28.47917900
     70.70089800  1
'MIA                          '          452.61000000        49.89600000        80.62800000
    135.06700000  1
'DEN                          '          459.42969800        21.39288300        31.12820700
     54.10527000  1
'JFK                          '          523.90200000        72.78800000        41.24800000
     85.01100000  1
'PHX                          '          134.22583900         8.45468700        21.28586000
     26.88325800  1
'LAS                          '          177.80900000         8.80000000        13.95000000
     29.54100000  1
'EWR                          '          328.12500000        65.63800000        34.36100000
     56.57200000  1
'STL                          '          100.95479300         4.39379600        14.85487600
     24.46671000  1
'MSP                          '          104.30500000         9.03500000         4.17700000
     26.34100000  1
'BOS                          '          215.25740000         6.32681000        28.19096500
     50.53210300  1
```

Airportz.asc

```
'ATL                    '          173.49723500        18.89174400         7.57738500
     25.08172900          0.90000000  1
'LAX                    '          367.24000000        14.04000000        85.30900000
     70.13600000          1.00000000  1
'SFO                    '          244.50108100        32.58041600        28.47917900
     70.70089800          0.80000000  1
'MIA                    '          452.61000000        49.89600000        80.62800000
    135.06700000          0.80000000  1
'DEN                    '          459.42969800        21.39288300        31.12820700
     54.10527000          0.70000000  1
'JFK                    '          523.90200000        72.78800000        41.24800000
     85.01100000          0.75000000  1
'PHX                    '          134.22583900         8.45468700        21.28586000
     26.88325800          0.95000000  1
'LAS                    '          177.80900000         8.80000000        13.95000000
     29.54100000          0.80000000  1
'EWR                    '          328.12500000        65.63800000        34.36100000
     56.57200000          0.70000000  1
'STL                    '          100.95479300         4.39379600        14.85487600
     24.46671000          0.80000000  1
'MSP                    '          104.30500000         9.03500000         4.17700000
     26.34100000          0.60000000  1
'BOS                    '          215.25740000         6.32681000        28.19096500
     50.53210300          0.70000000  1
'RDU                    '           32.33231700         3.10233600         0.39670500
      6.17751900          0.80000000  1
'ORF                    '           15.47694800         1.19592800         3.06727100
      5.14329900          0.90000000  1
'RIC                    '           18.44374000         0.77435500         2.89782000
      6.16125200          0.90000000  1
'ROA                    '            5.23090700         0.50466000         0.86003700
      1.55425600          0.90000000  1
```

APPENDIX H

DEA MODEL LOG BY DMU SIZE

SUMMARY OF EFFICIENT DMUs

MODEL	DMUs	O/I	FORM	ORIEN	EVAL	DATA FILE	REMARKS	No. Eff.	% Eff	No. Ineff
AIRW03	4	2/2	CRS	I	STD ARCH	AIRPORT5	Minus y3, y4, y5, Minus x3, x4	3	75.00%	1
AIR5	4	2/3	CRS	O	INV	AIRPORT2	No enplanements	2	50.00%	2
AIR11	4	2/3	CRS	I	INV	AIRPORT2	No enplanements	2	50.00%	2
AIR042	4	2/3	CRS	I	STD ARCH	AIRPORT2		2	50.00%	2
AIR2	4	3/3	CRS	O	INV	AIRPORT2		3	75 00%	1
AIR8	4	3/3	CRS	I	INV	AIRPORT2		3	75.00%	1
AIR04	4	3/3	CRS	I	STD ARCH	AIRPORT2		3	75 00%	1
AIR010	4	3/3	CRS	I	STD ARCH	AIRPORT8	Minus y2 and x4	4	100.00%	0
AIR4X	4	5/4	CRS	I	STD ARCH	AIRPORT3		4	100 00%	0
AIRV5	4	2/3	VRS	O	INV	AIRPORT2	No enplanements	3	75.00%	1
AIRV11	4	2/3	VRS	I	INV	AIRPORT2	No enplanements	3	75.00%	1
AIRV2	4	3/3	VRS	O	INV	AIRPORT2		4	100.00%	0
AIRV8	4	3/3	VRS	I	INV	AIRPORT2		4	100 00%	0
AIRW06D	12	1/3	CRS	I	STD ARCH	AIRPORTB	Minus y2, y3, y4, Minus x4	4	33.33%	8
AIRW02	12	2/2	CRS	I	STD ARCH	AIRPORT4	Minus y3, y4, y5, Minus x3, x4	5	41.67%	7
AIR4	12	2/3	CRS	O	INV	AIRPORT1	No enplanements	4	33 33%	8
AIR10	12	2/3	CRS	I	INV	AIRPORT1	No enplanements	4	33.33%	8
AIR122	12	2/3	CRS	I	STD ARCH	AIRPORT1		4	33 33%	8
AIR1	12	3/3	CRS	O	INV	AIRPORT1		6	50 00%	6
AIR7	12	3/3	CRS	I	INV	AIRPORT1		6	50.00%	6
AIR12	12	3/3	CRS	I	STD ARCH	AIRPORT1		6	50 00%	6
AIR009	12	3/3	CRS	I	STD ARCH	AIRPORT7	Minus y2 and x4	6	50.00%	6
AIR005	12	4/3	CRS	I	STD ARCH	AIRPORT3	Operations CenterMinus y3, x4	11	91 67%	1
AIR12X	12	5/4	CRS	I	STD ARCH	AIRPORT3		10	83.33%	2
AIRV4	12	2/3	VRS	O	INV	AIRPORT1	No enplanements	8	66.67%	4
AIRV10	12	2/3	VRS	I	INV	AIRPORT1	No enplanements	8	66.67%	4
AIRV1	12	3/3	VRS	O	INV	AIRPORT1		8	66.67%	4
AIRV7	12	3/3	VRS	I	INV	AIRPORT1		8	66.67%	4
AIRW04	16	1/3	CRS	I	STD ARCH	AIRPORT6	Minus y2, y3, y4, Minus x4	5	31.25%	11
AIRW06A	16	1/3	CRS	I	STD ARCH	AIRPORT6	Minus y2, y3, y4, Minus x4	5	31.25%	11
AIRW06C	16	1/3	CRS	I	STD ARCH	AIRPORTA	Minus y2, y3, y4, Minus x4	4	25.00%	12
AIRW06C	16	1/3	CRS	O	STD ARCH	AIRPORTA		4	25.00%	12
AIRW01	16	2/2	CRS	I	STD ARCH	AIRPORT3	Minus y3, y4, y5, Minus x3, x4	5	31.25%	11
AIR3	16	2/3	CRS	O	INV	AIRPORT	No enplanements	6	37 50%	10
AIR9	16	2/3	CRS	I	INV	AIRPORT	No enplanements	6	37.50%	10
AIR162	16	2/3	CRS	I	STD ARCH	AIRPORT		6	37.50%	10
AIRW06	16	2/3	CRS	I	STD ARCH	AIRPORT3	Minus y3, y4, y5, Minus x4	7	43 75%	9
AIR011	16	2/3	CRS	I	STD ARCH	AIRPORT6	Minus y2, y4, x4	7	43 75%	9
AIRW05	16	2/3	CRS	I	STD ARCH	AIRPORT6	Minus y2, y3, Minus x4	7	43 75%	9
AIRW06B	16	2/3	CRS	I	STD ARCH	AIRPORT9	Minus y3, y4, y5, Minus x4	7	43 75%	9
AIRM05	16	2/3	CRS	I	STD ARCH	AIRPORTA	Minus y2, y5 and x4	8	50 00%	8
AIRW06E	16	2/3	CRS	I	STD ARCH	AIRPORTA	Minus y2, y4, Minus x4	8	50 00%	8
AIR003	16	2/4	CRS	I	STD ARCH	AIRPORT3	Minus y3,y5,y4	11	68.75%	5
AIR	16	3/3	CRS	O	INV	AIRPORT		8	50 00%	8
AIR6	16	3/3	CRS	I	INV	AIRPORT		8	50.00%	8
AIR16I	16	3/3	CRS	I	INV ARCH	AIRPORT		8	50 00%	8
AIR16	16	3/3	CRS	I	STD ARCH	AIRPORT		8	50 00%	8
AIR008	16	3/3	CRS	I	STD ARCH	AIRPORT6	Minus y2 and x4	8	50 00%	8

AIRM04	16	3/3	CRS	I	STD ARCH	AIRPORTA	Minus y2, x4	9	56.25%	7
AIR002	16	3/4	CRS	I	STD ARCH	AIRPORT3	Minus y3, y5	11	68.75%	5
AIR004	16	4/3	CRS	I	STD ARCH	AIRPORT3	Operations CenterMinus y3, x4	7	43.75%	9
AIR001	16	4/4	CRS	I	STD ARCH	AIRPORT3	Minus y3	12	75.00%	4
AIR16X1	16	4/4	CRS	I	STD ARCH	AIRPORT3		13	81.25%	3
AIR006	16	4/4	CRS	I	STD ARCH	AIRPORT6		12	75.00%	4
AIRM02	16	4/4	CRS	I	STD ARCH	AIRPORTA	COMBINED, (y1 and y2 added)	14	87.50%	2
AIRX	16	5/4	CRS	I	INV ARCH	AIRPORT3		13	81.25%	3
AIR16X	16	5/4	CRS	I	STD ARCH	AIRPORT3		13	81.25%	3
AIR16XR	16	5/4	CRS	I	STD ARCH	AIRPORT3		11	68.75%	5
AIRM01	16	5/4	CRS	I	STD ARCH	AIRPORT9	CONDENSED	14	87.50%	2
AIRZ01	16	¼	CRS	I	STD ARCH	AIRPORTZ	Minus y2, y3, y4, Minus x4	6	37.50%	10
AIRXX2	16	¼D/DDDN	CRS	I	STD ARCH	AIRPORTA		5	31.25%	11
AIR007	16	¾	CRS	I	STD ARCH	AIRPORT6	Minus y3 (Which is y2 in data file, since y1 and y2 are combined)	11	68.75%	5
AIRM03	16	¾	CRS	I	STD ARCH	AIRPORTA	Minus y2 (was y3)	12	75.00%	4
AIRW06CR	16	1/3N/NND	CRS	I	STD ARCH	AIRPORTA	Minus y2, y3, y4, Minus x4	4	25.00%	12
AIR01C	16	2/3DD/DDN	CRS	I	STD ARCH	AIRPORT9		7	43.75%	9
AIR9R	16	2/3NN/NND	CRS	I	STD ARCH	AIRPORT		6	37.50%	10
AIR01A	16	2/4DD/DDDN	CRS	I	STD ARCH	AIRPORT9	Cargo moved to input	7	43.75%	9
AIRXX4	16	2/4DD/DDDN	CRS	I	STD ARCH	AIRPORT9		10	62.50%	6
AIRXX3	16	2/4DD/DDDN	CRS	I	STD ARCH	AIRPORTA		10	62.50%	6
AIR01B	16	3/3DDD/DDN	CRS	I	STD ARCH	AIRPORT9		8	50.00%	8
AIRXX1	16	5/4DDDNN/DDDN	CRS	I	STD ARCH	AIRPORT3		13	81.25%	3
AIRW06CR	16	1/3	VRS	I	STD ARCH	AIRPORT		9	56.25%	7
AIRW06V	16	1/3	VRS	I	STD ARCH	AIRPORTA		9	56.25%	7
AIRW06C	16	1/3	VRS	I	STD ARCH	AIRPORTA		9	56.25%	7
AIRW06C	16	1/3	VRS	O	STD ARCH	AIRPORTA		9	56.25%	7
AIRV3	16	2/3	VRS	O	INV	AIRPORT	No enplanements	10	62.50%	6
AIRV9	16	2/3	VRS	I	INV	AIRPORT	No enplanements	10	62.50%	6
AIRV	16	3/3	VRS	O	INV	AIRPORT		11	68.75%	5
AIRV6	16	3/3	VRS	I	INV	AIRPORT		11	68.75%	5
AIRV16	16	3/3	VRS	I	INV ARCH	AIRPORT		11	68.75%	5

Model Count	80	
		Avg. Eff
4 DMUs	13	76.92%
12 DMUs	15	54.44%
16 DMUs	52	54.45%
	80	

APPENDIX I

OUTPUT AND INPUT STATISTICS

y1		x1		x2		x3	
Mean	209.5838099	Mean	19.86341344	Mean	24.90070656	Mean	42.09214338
Standard Error	42.75435212	Standard Error	5.830280945	Standard Error	6.543615345	Standard Error	8.977486182
Median	175.6531175	Median	8.9175	Median	18.070368	Median	28.212129
Mode	#N/A	Mode	#N/A	Mode	#N/A	Mode	#N/A
Standard Deviation	171.0174085	Standard Deviation	23.32112378	Standard Deviation	26.17446138	Standard Deviation	35.90994473
Sample Variance	29246.95401	Sample Variance	543.8748144	Sample Variance	685.1024285	Sample Variance	1289.52413
Kurtosis	-0.94304752	Kurtosis	0.901355955	Kurtosis	1.491339127	Kurtosis	1.545332056
Skewness	0.537337438	Skewness	1.425974406	Skewness	1.41442756	Skewness	1.158372106
Range	518.671093	Range	72.28334	Range	84.912295	Range	133.512744
Minimum	5.230907	Minimum	0.50466	Minimum	0.396705	Minimum	1.554256
Maximum	523.902	Maximum	72 788	Maximum	85.309	Maximum	135.067
Sum	3353.340958	Sum	317.814615	Sum	398.411305	Sum	673.474294
Count	16	Count	16	Count	16	Count	16
Confidence Level(95.0%)	91.12880042	Confidence Level(95.0%)	12.42695731	Confidence Level(95.0%)	13.94739453	Confidence Level(95.0%)	19.13507061

y1		y2		y3		y4		y5	
Mean	114 9275956	Mean	99 68779563	Mean	209 4241896	Mean	12.49378713	Mean	0 56009375
Standard Error	30 73594113	Standard Error	20.76881101	Standard Error	53 46124628	Standard Error	2 012452248	Standard Error	0 145105065
Median	73.568079	Median	104 27	Median	125 242	Median	13 2373545	Median	0 3705825
Mode	#N/A	Mode	#N/A	Mode	#N/A	Mode	#N/A	Mode	#N/A
Standard Deviation	122 9437645	Standard Deviation	83 07524404	Standard Deviation	213 844985	Standard Deviation	8.04980899	Standard Deviation	0 580420259
Sample Variance	15115 16923	Sample Variance	6901 496172	Sample Variance	45729 67762	Sample Variance	64 79942478	Sample Variance	0 336887677
Kurtosis	1.7328159	Kurtosis	1 768398316	Kurtosis	-0 374007927	Kurtosis	0 024355617	Kurtosis	-0 40099179
Skewness	1 524059592	Skewness	1.19476368	Skewness	0 945846176	Skewness	0 138662952	Skewness	0 99251352
Range	418 637535	Range	310 547558	Range	624 634981	Range	27 767833	Range	1 574604
Minimum	2 526465	Minimum	2 704442	Minimum	2.829996	Minimum	0 323145	Minimum	0 022618
Maximum	421 164	Maximum	313 252	Maximum	627 464977	Maximum	28 090978	Maximum	1 597222
Sum	1838 84153	Sum	1595 00473	Sum	3350 787033	Sum	199 900594	Sum	8 9615
Count	16	Count	16	Count	16	Count	16	Count	16
Confidence Level(95 0%)	65 51214802	Confidence Level(95 0%)	44 2677	Confidence Level(95 0%)	113 9500191	Confidence Level(95 0%)	4 289443065	Confidence Level(95 0%)	0 309284315

x1		x2		x3		x4	
Mean	19 86341344	Mean	48 28516156	Mean	42 09214338	Mean	252 3416958
Standard Error	5 830280945	Standard Error	12 4269208	Standard Error	8 977486182	Standard Error	55 84505079
Median	8 9175	Median	24 532243	Median	28 212129	Median	232 821
Mode	#N/A	Mode	#N/A	Mode	#N/A	Mode	#N/A
Standard Deviation	23 32112378	Standard Deviation	49 7076832	Standard Deviation	35 90994473	Standard Deviation	223 3802032
Sample Variance	543 8748144	Sample Variance	2470 853769	Sample Variance	1289 52413	Sample Variance	49898 71517
Kurtosis	0 901355955	Kurtosis	0 226792333	Kurtosis	1 545332056	Kurtosis	1 228449755
Skewness	1 425974406	Skewness	1 078843842	Skewness	1 158372106	Skewness	1 038670448
Range	72 28334	Range	160 81442	Range	133 512744	Range	817 273324
Minimum	0 50466	Minimum	0 72758	Minimum	1 554256	Minimum	3 404812
Maximum	72 788	Maximum	161 542	Maximum	135 067	Maximum	820 678136
Sum	317 814615	Sum	772 562585	Sum	673 474294	Sum	4037 467133
Count	16	Count	16	Count	16	Count	16
Confidence Level(95 0%)	12 42695731	Confidence Level(95 0%)	26 48737097	Confidence Level(95 0%)	19 13507061	Confidence Level(95 0%)	119 0309813

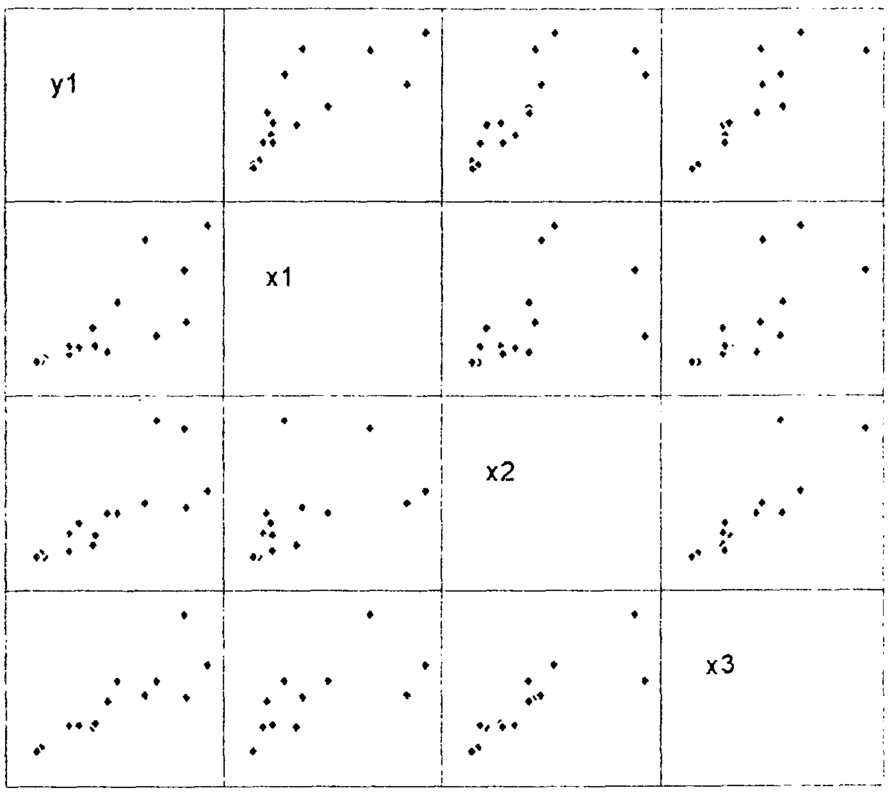
APPENDIX J

CORRELATION OF OUTPUT AND INPUTS

For original output and inputs :

Pearson Correlations

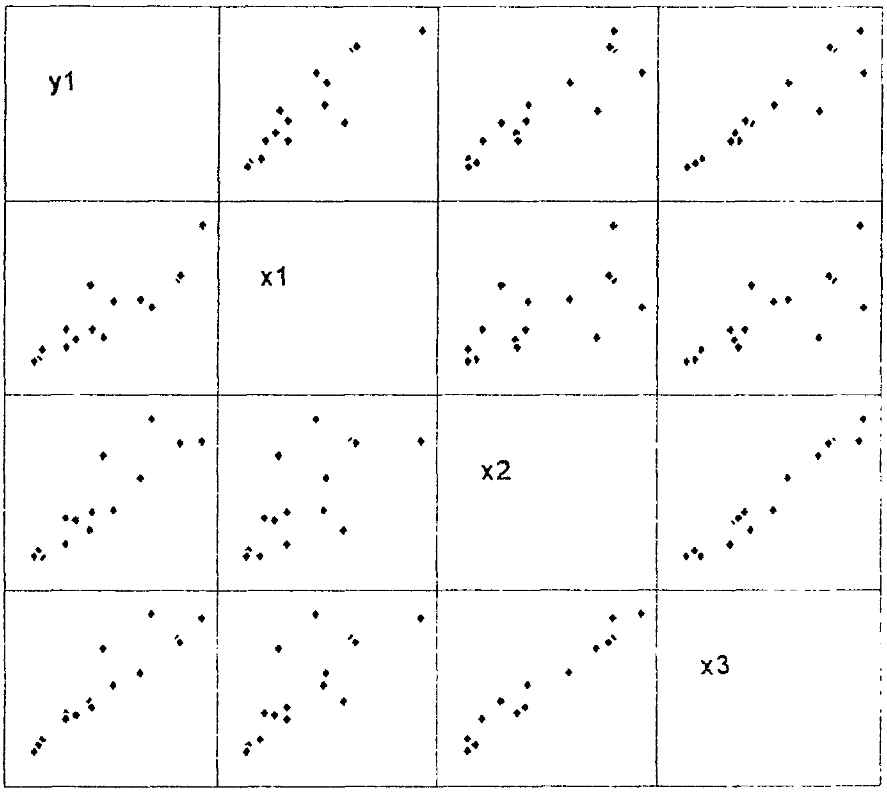
	y1	x1	x2	x3
y1	1.000	0.793	0.793	0.876
x1		1.000	0.534	0.746
x2			1.000	0.877
x3				1.000



For projected output and inputs :

Pearson Correlations

	y1	x1	x2	x3
y1	1.000	0.910	0.917	0.941
x1		1.000	0.708	0.799
x2			1.000	0.980
x3				1.000



APPENDIX K

MODEL OUTPUTS FOR

AIRW06C, AIRW06D, and AIRW06V

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Environment File : AIRPORTA.DBF

Data base file...............................: AIRPORTA.DBF
Number of DMUs in the Reference Set..........: 16
Number of output columns.....................: 1
Number of Input columns......................: 3
Number of Analysis sets......................: 1

Output field	Type	Scale	Translate
OUTPUT1	OUTPUT-D	1.00	0.00

Input field	Type	Scale	Translate
INPUT1	INPUT--D	1.00	0.00
INPUT2	INPUT--D	1.00	0.00
INPUT3	INPUT--D	1.00	0.00

Reference set condition......................: All DMUs
Analysis set condition.......................: All DMUs
Surface......................................: VRS
Variant......................................: Invariant NonArchimedean
Orientation..................................: Input
Convertion...................................: X
ASCII file...................................: AIRPORTA.ASC

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DMU	NAME	EFFICIENCY SCORES IOTA		CRS/I/STA/EPS THETA
1	ATL		1.00000	1.00000
2	LAX	.96357-EPS(	44.172)	.96357
3	SFO	.46681-EPS(	.000)	.46681
4	MIA	.41449-EPS(	1.304)	.41449
5	DEN		1.00000	1.00000
6	JFK	.77303-EPS(	22.528)	.77303
7	PHX	.69112-EPS(	4.119)	.69112
8	LAS	.91760-EPS(	4.773)	.91760
9	EWR	.68306-EPS(	30.795)	.68306
10	STL	.80725-EPS(	.904)	.80725
11	MSP	.87410-EPS(	6.228)	.87410
12	BOS		1.00000	1.00000
13	RDU		1.00000	1.00000
14	ORF	.50654-EPS(	.082)	.50654
15	RIC	.76735-EPS(	.753)	.76735
16	ROA	.46032-EPS(	.023)	.46032

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DMU	NAME	DISTANCE MEASURES DELTA		CRS/I/STA/EPS SIGMA	
1	ATL	.000+EPS(	.000)	.000+EPS(	.000)
2	LAX	.036+EPS(	44.172)	.000+EPS(	44.172)
3	SFO	.533+EPS(	.000)	.000+EPS(	.000)
4	MIA	.586+EPS(	1.304)	.000+EPS(	1.304)
5	DEN	.000+EPS(	.000)	.000+EPS(	.000)
6	JFK	.227+EPS(	22.528)	.000+EPS(	22.528)
7	PHX	.309+EPS(	4.119)	.000+EPS(	4.119)
8	LAS	.082+EPS(	4.773)	.000+EPS(	4.773)
9	EWR	.317+EPS(	30.795)	.000+EPS(	30.795)
10	STL	.193+EPS(	.904)	.000+EPS(	.904)
11	MSP	.126+EPS(	6.228)	.000+EPS(	6.228)
12	BOS	.000+EPS(	.000)	.000+EPS(	.000)
13	RDU	.000+EPS(	.000)	.000+EPS(	.000)
14	ORF	.493+EPS(	.082)	.000+EPS(	.082)
15	RIC	.233+EPS(	.753)	.000+EPS(	.753)
16	ROA	.540+EPS(	.023)	.000+EPS(	.023)

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DMU	NAME	VIRTUAL I/O	XI	CRS/I/STA/EPS	CHI
1	ATL	1.000+EPS(	.000)	1.000+EPS(	.000)
2	LAX	1.000+EPS(	.000)	.964+EPS(	-44.172)
3	SFO	1.000+EPS(	.000)	.467+EPS(	.000)
4	MIA	1.000+EPS(	.000)	.414+EPS(	-1.304)
5	DEN	1.000+EPS(	.000)	1.000+EPS(	.000)
6	JFK	1.000+EPS(	.000)	.773+EPS(	-22.528)
7	PHX	1.000+EPS(	.000)	.691+EPS(	-4.119)
8	LAS	1.000+EPS(	.000)	.918+EPS(	-4.773)
9	EWR	1.000+EPS(	.000)	.683+EPS(	-30.795)
10	STL	1.000+EPS(	.000)	.807+EPS(	-.904)
11	MSP	1.000+EPS(	.000)	.874+EPS(	-6.228)
12	BOS	1.000+EPS(	.000)	1.000+EPS(	.000)
13	RDU	1.000+EPS(	.000)	1.000+EPS(	.000)
14	ORF	1.000+EPS(	.000)	.507+EPS(	-.082)
15	RIC	1.000+EPS(	.000)	.767+EPS(	-.753)
16	ROA	1.000+EPS(	.000)	.460+EPS(	-.023)

SLACK AND EXCESS CRS/I/STA/EPS

DMU	NAME	OUTPUT1	INPUT1	INPUT2	INPUT3
1	ATL	.00	.00	.00	.00
2	LAX	.00	.00	44.17	.00
3	SFO	.00	.00	.00	.00
4	MIA	.00	.00	1.30	.00
5	DEN	.00	.00	.00	.00
6	JFK	.00	22.53	.00	.00
7	PHX	.00	.00	4.12	.00
8	LAS	.00	.00	.00	4.77
9	EWR	.00	29.56	1.24	.00
10	STL	.00	.00	.90	.00
11	MSP	.00	.00	.00	6.23
12	BOS	.00	.00	.00	.00
13	RDU	.00	.00	.00	.00
14	ORF	.00	.00	.08	.00
15	RIC	.00	.00	.00	.75
16	ROA	.00	.00	.00	.02

PRICES (MULTIPLIERS) CRS/I/STA/EPS

DMU	NAME	OUTPUT1	INPUT1	INPUT2	INPUT3
1	ATL	.00576	.00321	.03741	.02616
2	LAX	.00262	.04109	EPS	.00603
3	SFO	.00191	.00106	.01239	.00866
4	MIA	.00092	.01434	EPS	.00211
5	DEN	.00218	EPS	EPS	.01848
6	JFK	.00148	EPS	.00850	.00764
7	PHX	.00515	.08064	EPS	.01184
8	LAS	.00516	.07943	.02158	EPS
9	EWR	.00208	EPS	EPS	.01768
10	STL	.00800	.12523	EPS	.01838
11	MSP	.00838	.07841	.06980	EPS
12	BOS	.00465	.07276	EPS	.01068
13	RDU	.03093	.01720	.20072	.14035
14	ORF	.03273	.51258	EPS	.07524
15	RIC	.04161	.64037	.17397	EPS
16	ROA	.08800	1.35445	.36796	EPS

DEA REPORT

```
DEA:
NAME: ATL                         MODEL: CRS/I/STA/EPS
Unit:    1                        Number of Units in Analysis:   16
-----------------------------------------------------------------
---------------       DATA      PROJECTED INEFFICIENCY      PRICE
Outputs...
OUTPUT1   (D)       173.50        173.50          .00      .00576
Inputs....
INPUT1    (D)        18.89         18.89          .00      .00321
INPUT2    (D)         7.58          7.58          .00      .03741
INPUT3    (D)        25.08         25.08          .00      .02616
-----------------------------------------------------------------

Iota:                      1.00000 Theta:                 1.00000
Delta:      .000+EPS(        .000) Sigma:      .000+EPS(     .000)
V-input:   1.000+EPS(        .000) V-output:  1.000+EPS(     .000)

Comparison Set:
DEN         .00000        ATL        1.00000        RDU    .00000
```

DEA REPORT

DEA:
NAME: LAX MODEL: CRS/I/STA/EPS
Unit: 2 Number of Units in Analysis: 16

		DATA	PROJECTED	INEFFICIENCY	PRICE
Outputs...					
OUTPUT1	(D)	367.24	367.24	.00	.00262
Inputs....					
INPUT1	(D)	14.04	13.53	-.51	.04109
INPUT2	(D)	85.31	38.03	-47.28	EPS
INPUT3	(D)	70.14	67.58	-2.56	.00603

Analysis of Projection------------

	Proportional	Residual..
OUTPUT1	.000	.000
INPUT1	.512	.000
INPUT2	3.108	44.172
INPUT3	2.555	.000

Iota:	.96357-EPS(	44.172)	Theta:		.96357
Delta:	.036+EPS(	44.172)	Sigma:	.000+EPS(	44.172)
V-input:	1.000+EPS(	.000)	V-output:	.964+EPS(	-44.172)

Comparison Set:
DEN .34662 BOS .96625

DEA REPORT

DEA:
NAME: SFO MODEL: CRS/I/STA/EPS
Unit: 3 Number of Units in Analysis: 16

	DATA	PROJECTED	INEFFICIENCY	PRICE
Outputs...				
OUTPUT1 (D)	244.50	244.50	.00	.00191
Inputs....				
INPUT1 (D)	32.58	15.21	-17.37	.00106
INPUT2 (D)	28.48	13.29	-15.18	.01239
INPUT3 (D)	70.70	33.00	-37.70	.00866

Analysis of Projection-----------

	Proportional	Residual..
OUTPUT1	.000	.000
INPUT1	17.371	.000
INPUT2	15.185	.000
INPUT3	37.697	.000

Iota:	.46681-EPS(	.000)	Theta:		.46681
Delta:	.533+EPS(	.000)	Sigma:	.000+EPS(	.000)
V-input:	1.000+EPS(	.000)	V-output:	.467+EPS(	.000)

Comparison Set:

DEN	.37637	ATL	.12855	RDU	1.52429

DEA REPORT

DEA:
NAME: MIA | MODEL: CRS/I/STA/EPS
Unit: 4 | Number of Units in Analysis: 16

	DATA	PROJECTED	INEFFICIENCY	PRICE
Outputs...				
OUTPUT1 (D)	452.61	452.61	.00	.00092
Inputs....				
INPUT1 (D)	49.90	20.68	-29.21	.01434
INPUT2 (D)	80.63	32.12	-48.51	EPS
INPUT3 (D)	135.07	55.98	-79.08	.00211

Analysis of Projection

	Proportional	Residual..
OUTPUT1	.000	.000
INPUT1	29.214	.000
INPUT2	47.208	1.304
INPUT3	79.083	.000

Iota:	.41449-EPS(	1.304)	Theta:		.41449
Delta:	.586+EPS(	1.304)	Sigma:	.000+EPS(	1.304)
V-input:	1.000+EPS(	.000)	V-output:	.414+EPS(	-1.304)

Comparison Set:

DEN	.93525	BOS	.10652

DEA REPORT

DEA:
NAME: DEN MODEL: CRS/I/STA/EPS
Unit: 5 Number of Units in Analysis: 16

	DATA	PROJECTED	INEFFICIENCY	PRICE
Outputs...				
OUTPUT1 (D)	459.43	459.43	.00	.00218
Inputs....				
INPUT1 (D)	21.39	21.39	.00	EPS
INPUT2 (D)	31.13	31.13	.00	EPS
INPUT3 (D)	54.11	54.11	.00	.01848

Iota: 1.00000 Theta: 1.00000
Delta: .000+EPS(.000) Sigma: .000+EPS(.000)
V-input: 1.000+EPS(.000) V-output: 1.000+EPS(.000)

Comparison Set:
DEN 1.00000

DEA REPORT

DEA:
NAME: JFK MODEL: CRS/I/STA/EPS
Unit: 6 Number of Units in Analysis: 16

		DATA	PROJECTED	INEFFICIENCY	PRICE
Outputs...					
OUTPUT1	(D)	523.90	523.90	.00	.00148
Inputs....					
INPUT1	(D)	72.79	33.74	-39.05	EPS
INPUT2	(D)	41.25	31.89	-9.36	.00850
INPUT3	(D)	85.01	65.72	-19.29	.00764

Analysis of Projection------------

	Proportional	Residual..
OUTPUT1	.000	.000
INPUT1	16.521	22.528
INPUT2	9.362	.000
INPUT3	19.295	.000

Iota:	.77303-EPS(	22.528)	Theta:		.77303
Delta:	.227+EPS(	22.528)	Sigma:	.000+EPS(	22.528)
V-input:	1.000+EPS(	.000)	V-output:	.773+EPS(	-22.528)

Comparison Set:
DEN .81397 ATL .86421

DEA REPORT

DEA:
NAME: PHX — MODEL: CRS/I/STA/EPS
Unit: 7 — Number of Units in Analysis: 16

		DATA	PROJECTED	INEFFICIENCY	PRICE
Outputs...					
OUTPUT1	(D)	134.23	134.23	.00	.00515
Inputs....					
INPUT1	(D)	8.45	5.84	-2.61	.08064
INPUT2	(D)	21.29	10.59	-10.69	EPS
INPUT3	(D)	26.88	18.58	-8.30	.01184

Analysis of Projection------------

	Proportional	Residual..
OUTPUT1	.000	.000
INPUT1	2.612	.000
INPUT2	6.575	4.119
INPUT3	8.304	.000

Iota:	.69112-EPS(	4.119)	Theta:		.69112
Delta:	.309+EPS(	4.119)	Sigma:	.000+EPS(	4.119)
V-input:	1.000+EPS(	.000)	V-output:	.691+EPS(	-4.119)

Comparison Set:

DEN	.24058	BOS	.11009

DEA REPORT

DEA:
NAME: LAS — MODEL: CRS/I/STA/EPS
Unit: 8 — Number of Units in Analysis: 16

	DATA	PROJECTED	INEFFICIENCY	PRICE
Outputs...				
OUTPUT1 (D)	177.81	177.81	.00	.00516
Inputs....				
INPUT1 (D)	8.80	8.07	-.73	.07943
INPUT2 (D)	13.95	12.80	-1.15	.02158
INPUT3 (D)	29.54	22.33	-7.21	EPS

Analysis of Projection

	Proportional	Residual..
OUTPUT1	.000	.000
INPUT1	.725	.000
INPUT2	1.149	.000
INPUT3	2.434	4.773

Iota:	.91760-EPS(4.773)	Theta:		.91760
Delta:	.082+EPS(4.773)	Sigma:	.000+EPS(	4.773)
V-input:	1.000+EPS(.000)	V-output:	.918+EPS(	-4.773)

Comparison Set:

DEN	.36108	BOS	.05536

DEA REPORT

DEA:
NAME: EWR
Unit: 9

MODEL: CRS/I/STA/EPS
Number of Units in Analysis: 16

		DATA	PROJECTED	INEFFICIENCY	PRICE
Outputs...					
OUTPUT1	(D)	328.13	328.13	.00	.00208
Inputs....					
INPUT1	(D)	65.64	15.28	-50.36	EPS
INPUT2	(D)	34.36	22.23	-12.13	EPS
INPUT3	(D)	56.57	38.64	-17.93	.01768

Analysis of Projection

	Proportional	Residual..
OUTPUT1	.000	.000
INPUT1	20.803	29.556
INPUT2	10.890	1.239
INPUT3	17.930	.000

Iota: .68306-EPS(30.795) Theta: .68306
Delta: .317+EPS(30.795) Sigma: .000+EPS(30.795)
V-input: 1.000+EPS(.000) V-output: .683+EPS(-30.795)

Comparison Set:
DEN .71420

DEA REPORT

DEA:
NAME: STL MODEL: CRS/I/STA/EPS
Unit: 10 Number of Units in Analysis: 16

	DATA	PROJECTED	INEFFICIENCY	PRICE
Outputs...				
OUTPUT1 (D)	100.95	100.95	.00	.00800
Inputs....				
INPUT1 (D)	4.39	3.55	-.85	.12523
INPUT2 (D)	14.85	11.09	-3.77	EPS
INPUT3 (D)	24.47	19.75	-4.72	.01838

Analysis of Projection------------

	Proportional	Residual..
OUTPUT1	.000	.000
INPUT1	.847	.000
INPUT2	2.863	.904
INPUT3	4.716	.000

Iota:	.80725-EPS(	.904)	Theta:		.80725
Delta:	.193+EPS(	.904)	Sigma:	.000+EPS(	.904)
V-input:	1.000+EPS(	.000)	V-output:	.807+EPS(	-.904)

Comparison Set:

DEN	.07347	BOS	.31219

DEA REPORT

```
DEA:
NAME: MSP                              MODEL: CRS/I/STA/EPS
Unit:    11                            Number of Units in Analysis:   16
----------------------------------------------------------------------
---------------        DATA      PROJECTED INEFFICIENCY          PRICE
Outputs...
OUTPUT1   (D)        104.31         104.31          .00         .00838
Inputs....
INPUT1    (D)          9.04           7.90        -1.14         .07841
INPUT2    (D)          4.18           3.65         -.53         .06980
INPUT3    (D)         26.34          16.80        -9.54            EPS
----------------------------------------------------------------------

Analysis of Projection-----------
          Proportional  Residual..
OUTPUT1           .000        .000
INPUT1           1.138        .000
INPUT2            .526        .000
INPUT3           3.316       6.228
----------------------------------

Iota:     .87410-EPS(      6.228) Theta:                        .87410
Delta:      .126+EPS(      6.228) Sigma:        .000+EPS(      6.228)
V-input:  1.000+EPS(        .000) V-output:     .874+EPS(     -6.228)

Comparison Set:
DEN         .09303          RDU       1.90418
```

DEA REPORT

DEA:
NAME: BOS — MODEL: CRS/I/STA/EPS
Unit: 12 — Number of Units in Analysis: 16

---------------	DATA	PROJECTED	INEFFICIENCY	PRICE
Outputs...				
OUTPUT1 (D)	215.26	215.26	.00	.00465
Inputs....				
INPUT1 (D)	6.33	6.33	.00	.07276
INPUT2 (D)	28.19	28.19	.00	EPS
INPUT3 (D)	50.53	50.53	.00	.01068

Iota:	1.00000	Theta:	1.00000
Delta:	.000+EPS(.000)	Sigma:	.000+EPS(.000)
V-input:	1.000+EPS(.000)	V-output:	1.000+EPS(.000)

Comparison Set:

DEN	.00000	BOS	1.00000

DEA REPORT

DEA:
NAME: RDU
Unit: 13

MODEL: CRS/I/STA/EPS
Number of Units in Analysis: 16

	DATA	PROJECTED	INEFFICIENCY	PRICE
Outputs...				
OUTPUT1 (D)	32.33	32.33	.00	.03093
Inputs....				
INPUT1 (D)	3.10	3.10	.00	.01720
INPUT2 (D)	.40	.40	.00	.20072
INPUT3 (D)	6.18	6.18	.00	.14035

Iota: 1.00000 Theta: 1.00000
Delta: .000+EPS(.000) Sigma: .000+EPS(.000)
V-input: 1.000+EPS(.000) V-output: 1.000+EPS(.000)

Comparison Set:

DEN	.00000	ATL	.00000	RDU	1.00000

DEA REPORT

DEA:
NAME: ORF MODEL: CRS/I/STA/EPS
Unit: 14 Number of Units in Analysis: 16

	DATA	PROJECTED	INEFFICIENCY	PRICE
Outputs...				
OUTPUT1 (D)	15.48	15.48	.00	.03273
Inputs....				
INPUT1 (D)	1.20	.61	-.59	.51258
INPUT2 (D)	3.07	1.47	-1.60	EPS
INPUT3 (D)	5.14	2.61	-2.54	.07524

Analysis of Projection

	Proportional	Residual..
OUTPUT1	.000	.000
INPUT1	.590	.000
INPUT2	1.514	.082
INPUT3	2.538	.000

Iota:	.50654-EPS(	.082)	Theta:		.50654
Delta:	.493+EPS(	.082)	Sigma:	.000+EPS(	.082)
V-input:	1.000+EPS(	.000)	V-output:	.507+EPS(	-.082)

Comparison Set:

DEN	.01913	BOS	.03108

DEA REPORT

DEA:
NAME: RIC — MODEL: CRS/I/STA/EPS
Unit: 15 — Number of Units in Analysis: 16

		DATA	PROJECTED	INEFFICIENCY	PRICE
Outputs...					
OUTPUT1	(D)	18.44	18.44	.00	.04161
Inputs....					
INPUT1	(D)	.77	.59	-.18	.64037
INPUT2	(D)	2.90	2.22	-.67	.17397
INPUT3	(D)	6.16	3.97	-2.19	EPS

Analysis of Projection-----------

	Proportional	Residual..
OUTPUT1	.000	.000
INPUT1	.180	.000
INPUT2	.674	.000
INPUT3	1.433	.753

Iota:	.76735-EPS(	.753)	Theta:		.76735
Delta:	.233+EPS(	.753)	Sigma:	.000+EPS(	.753)
V-input:	1.000+EPS(	.000)	V-output:	.767+EPS(	-.753)

Comparison Set:

BOS	.07159	DEN	.00660

DEA REPORT

DEA:

NAME: ROA		MODEL: CRS/I/STA/EPS		
Unit: 16		Number of Units in Analysis: 16		

---------------	DATA	PROJECTED	INEFFICIENCY	PRICE
Outputs...				
OUTPUT1 (D)	5.23	5.23	.00	.08800
Inputs....				
INPUT1 (D)	.50	.23	-.27	1.35445
INPUT2 (D)	.86	.40	-.46	.36796
INPUT3 (D)	1.55	.69	-.86	EPS

Analysis of Projection-----------

	Proportional	Residual..
OUTPUT1	.000	.000
INPUT1	.272	.000
INPUT2	.464	.000
INPUT3	.839	.023

Iota:	.46032-EPS(	.023)	Theta:		.46032
Delta:	.540+EPS(	.023)	Sigma:	.000+EPS(	.023)
V-input:	1.000+EPS(	.000)	V-output:	.460+EPS(	-.023)

Comparison Set:

BOS	.00305	DEN	.00996

INEFFICIENCY CRS/I/STA/EPS

DMU	NAME	OUTPUT1	INPUT1	INPUT2	INPUT3
1	ATL	.00	.00	.00	.00
2	LAX	.00	-.51	-47.28	-2.56
3	SFO	.00	-17.37	-15.18	-37.70
4	MIA	.00	-29.21	-48.51	-79.08
5	DEN	.00	.00	.00	.00
6	JFK	.00	-39.05	-9.36	-19.29
7	PHX	.00	-2.61	-10.69	-8.30
8	LAS	.00	-.73	-1.15	-7.21
9	EWR	.00	-50.36	-12.13	-17.93
10	STL	.00	-.85	-3.77	-4.72
11	MSP	.00	-1.14	-.53	-9.54
12	BOS	.00	.00	.00	.00
13	RDU	.00	.00	.00	.00
14	ORF	.00	-.59	-1.60	-2.54
15	RIC	.00	-.18	-.67	-2.19
16	ROA	.00	-.27	-.46	-.86

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Environment File : AIRPORTB.DBF

Data base file..............................: AIRPORTB.DBF
Number of DMUs in the Reference Set.........: 12
Number of output columns....................: 1
Number of Input columns.....................: 3
Number of Analysis sets.....................: 1

Output field	Type	Scale	Translate
OUTPUT1	OUTPUT-D	1.00	0.00

Input field	Type	Scale	Translate
INPUT1	INPUT--D	1.00	0.00
INPUT2	INPUT--D	1.00	0.00
INPUT3	INPUT--D	1.00	0.00

Reference set condition.....................: All DMUs
Analysis set condition......................: All DMUs
Surface.....................................: CRS
Variant.....................................: Invariant NonArchimedean
Orientation.................................: Input
Convertion..................................: X
ASCII file..................................: AIRPORTB.ASC

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DMU	NAME	EFFICIENCY SCORES IOTA	CRS/I/STA/EPS THETA
1	ATL	1.00000	1.00000
2	LAX	.96357-EPS(44.172)	.96357
3	SFO	.49933-EPS(.000)	.49933
4	MIA	.41449-EPS(1.304)	.41449
5	DEN	1.00000	1.00000
6	JFK	.77303-EPS(22.528)	.77303
7	PHX	.69112-EPS(4.119)	.69112
8	LAS	.91760-EPS(4.773)	.91760
9	EWR	.68306-EPS(30.795)	.68306
10	STL	.80725-EPS(.904)	.80725
11	MSP	1.00000	1.00000
12	BOS	1.00000	1.00000

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DMU	NAME	DISTANCE MEASURES DELTA		CRS/I/STA/EPS SIGMA	
1	ATL	.000+EPS(	.000)	.000+EPS(	.000)
2	LAX	.036+EPS(	44.172)	.000+EPS(	44.172)
3	SFO	.501+EPS(	.000)	.000+EPS(	.000)
4	MIA	.586+EPS(	1.304)	.000+EPS(	1.304)
5	DEN	.000+EPS(	.000)	.000+EPS(	.000)
6	JFK	.227+EPS(	22.528)	.000+EPS(	22.528)
7	PHX	.309+EPS(	4.119)	.000+EPS(	4.119)
8	LAS	.082+EPS(	4.773)	.000+EPS(	4.773)
9	EWR	.317+EPS(	30.795)	.000+EPS(	30.795)
10	STL	.193+EPS(	.904)	.000+EPS(	.904)
11	MSP	.000+EPS(	.000)	.000+EPS(	.000)
12	BOS	.000+EPS(	.000)	.000+EPS(	.000)

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DMU	NAME	VIRTUAL I/O	XI	CRS/I/STA/EPS	CHI
1	ATL	1.000+EPS(	.000)	1.000+EPS(	.000)
2	LAX	1.000+EPS(	.000)	.964+EPS(	-44.172)
3	SFO	1.000+EPS(	.000)	.499+EPS(	.000)
4	MIA	1.000+EPS(	.000)	.414+EPS(	-1.304)
5	DEN	1.000+EPS(	.000)	1.000+EPS(	.000)
6	JFK	1.000+EPS(	.000)	.773+EPS(	-22.528)
7	PHX	1.000+EPS(	.000)	.691+EPS(	-4.119)
8	LAS	1.000+EPS(	.000)	.918+EPS(	-4.773)
9	EWR	1.000+EPS(	.000)	.683+EPS(	-30.795)
10	STL	1.000+EPS(	.000)	.807+EPS(	-.904)
11	MSP	1.000+EPS(	.000)	1.000+EPS(	.000)
12	BOS	1.000+EPS(	.000)	1.000+EPS(	.000)

SLACK AND EXCESS CRS/I/STA/EPS

DMU	NAME	OUTPUT1	INPUT1	INPUT2	INPUT3
1	ATL	.00	.00	.00	.00
2	LAX	.00	.00	44.17	.00
3	SFO	.00	.00	.00	.00
4	MIA	.00	.00	1.30	.00
5	DEN	.00	.00	.00	.00
6	JFK	.00	22.53	.00	.00
7	PHX	.00	.00	4.12	.00
8	LAS	.00	.00	.00	4.77
9	EWR	.00	29.56	1.24	.00
10	STL	.00	.00	.90	.00
11	MSP	.00	.00	.00	.00
12	BOS	.00	.00	.00	.00

PRICES (MULTIPLIERS) CRS/I/STA/EPS

DMU	NAME	OUTPUT1	INPUT1	INPUT2	INPUT3
1	ATL	.00576	.02053	.06009	.00625
2	LAX	.00262	.04109	EPS	.00603
3	SFO	.00204	.00727	.02129	.00222
4	MIA	.00092	.01434	EPS	.00211
5	DEN	.00218	EPS	EPS	.01848
6	JFK	.00148	EPS	.00850	.00764
7	PHX	.00515	.08064	EPS	.01184
8	LAS	.00516	.07943	.02158	EPS
9	EWR	.00208	EPS	EPS	.01768
10	STL	.00800	.12523	EPS	.01838
11	MSP	.00959	.03415	.09996	.01040
12	BOS	.00465	.07276	EPS	.01068

DEA REPORT

```
DEA:
NAME: ATL                            MODEL: CRS/I/STA/EPS
Unit:    1                           Number of Units in Analysis:   12
-----------------------------------------------------------------------
---------------        DATA      PROJECTED INEFFICIENCY          PRICE
Outputs...
OUTPUT1   (D)        173.50         173.50           .00          .00576
Inputs....
INPUT1    (D)         18.89          18.89           .00          .02053
INPUT2    (D)          7.58           7.58           .00          .06009
INPUT3    (D)         25.08          25.08           .00          .00625
-----------------------------------------------------------------------

Iota:                       1.00000 Theta:                       1.00000
Delta:      .000+EPS(         .000) Sigma:       .000+EPS(         .000)
V-input:   1.000+EPS(         .000) V-output:   1.000+EPS(         .000)

Comparison Set:
DEN        .00000         ATL        1.00000           MSP        .00000
```

DEA REPORT

DEA:
NAME: LAX MODEL: CRS/I/STA/EPS
Unit: 2 Number of Units in Analysis: 12

	DATA	PROJECTED	INEFFICIENCY	PRICE
Outputs...				
OUTPUT1 (D)	367.24	367.24	.00	.00262
Inputs....				
INPUT1 (D)	14.04	13.53	-.51	.04109
INPUT2 (D)	85.31	38.03	-47.28	EPS
INPUT3 (D)	70.14	67.58	-2.56	.00603

Analysis of Projection-----------

	Proportional	Residual..
OUTPUT1	.000	.000
INPUT1	.512	.000
INPUT2	3.108	44.172
INPUT3	2.555	.000

Iota:	.96357-EPS(	44.172)	Theta:		.96357
Delta:	.036+EPS(	44.172)	Sigma:	.000+EPS(	44.172)
V-input:	1.000+EPS(	.000)	V-output:	.964+EPS(	-44.172)

Comparison Set:

DEN	.34662	BOS	.96625

DEA REPORT

DEA:
NAME: SFO MODEL: CRS/I/STA/EPS
Unit: 3 Number of Units in Analysis: 12

---------------	DATA	PROJECTED	INEFFICIENCY	PRICE
Outputs...				
OUTPUT1 (D)	244.50	244.50	.00	.00204
Inputs....				
INPUT1 (D)	32.58	16.27	-16.31	.00727
INPUT2 (D)	28.48	14.22	-14.26	.02129
INPUT3 (D)	70.70	35.30	-35.40	.00222

Analysis of Projection------------

	Proportional	Residual..
OUTPUT1	.000	.000
INPUT1	16.312	.000
INPUT2	14.259	.000
INPUT3	35.398	.000

Iota:	.49933-EPS(	.000)	Theta:		.49933
Delta:	.501+EPS(	.000)	Sigma:	.000+EPS(	.000)
V-input:	1.000+EPS(	.000)	V-output:	.499+EPS(	.000)

Comparison Set:

DEN	.33247	ATL	.31266	MSP	.35961

DEA REPORT

DEA:
NAME: MIA — MODEL: CRS/I/STA/EPS
Unit: 4 — Number of Units in Analysis: 12

	DATA	PROJECTED	INEFFICIENCY	PRICE
Outputs...				
OUTPUT1 (D)	452.61	452.61	.00	.00092
Inputs....				
INPUT1 (D)	49.90	20.68	-29.21	.01434
INPUT2 (D)	80.63	32.12	-48.51	EPS
INPUT3 (D)	135.07	55.98	-79.08	.00211

Analysis of Projection

	Proportional	Residual..
OUTPUT1	.000	.000
INPUT1	29.214	.000
INPUT2	47.208	1.304
INPUT3	79.083	.000

Iota:	.41449-EPS(1.304)	Theta:		.41449
Delta:	.586+EPS(1.304)	Sigma:	.000+EPS(	1.304)
V-input:	1.000+EPS(.000)	V-output:	.414+EPS(	-1.304)

Comparison Set:

DEN	.93525	BOS	.10652

DEA REPORT

DEA:
NAME: DEN MODEL: CRS/I/STA/EPS
Unit: 5 Number of Units in Analysis: 12

	DATA	PROJECTED	INEFFICIENCY	PRICE
Outputs...				
OUTPUT1 (D)	459.43	459.43	.00	.00218
Inputs....				
INPUT1 (D)	21.39	21.39	.00	EPS
INPUT2 (D)	31.13	31.13	.00	EPS
INPUT3 (D)	54.11	54.11	.00	.01848

Iota: 1.00000 Theta: 1.00000
Delta: .000+EPS(.000) Sigma: .000+EPS(.000)
V-input: 1.000+EPS(.000) V-output: 1.000+EPS(.000)

Comparison Set:
DEN 1.00000

DEA REPORT

DEA:
NAME: JFK — MODEL: CRS/I/STA/EPS
Unit: 6 — Number of Units in Analysis: 12

		DATA	PROJECTED	INEFFICIENCY	PRICE
Outputs...					
OUTPUT1	(D)	523.90	523.90	.00	.00148
Inputs....					
INPUT1	(D)	72.79	33.74	-39.05	EPS
INPUT2	(D)	41.25	31.89	-9.36	.00850
INPUT3	(D)	85.01	65.72	-19.29	.00764

Analysis of Projection-----------

	Proportional	Residual..
OUTPUT1	.000	.000
INPUT1	16.521	22.528
INPUT2	9.362	.000
INPUT3	19.295	.000

Iota:	.77303-EPS(	22.528)	Theta:		.77303
Delta:	.227+EPS(	22.528)	Sigma:	.000+EPS(	22.528)
V-input:	1.000+EPS(	.000)	V-output:	.773+EPS(	-22.528)

Comparison Set:

DEN	.81397	ATL	.86421

DEA REPORT

DEA:
NAME: PHX — MODEL: CRS/I/STA/EPS
Unit: 7 — Number of Units in Analysis: 12

		DATA	PROJECTED	INEFFICIENCY	PRICE
Outputs...					
OUTPUT1	(D)	134.23	134.23	.00	.00515
Inputs....					
INPUT1	(D)	8.45	5.84	-2.61	.08064
INPUT2	(D)	21.29	10.59	-10.69	EPS
INPUT3	(D)	26.88	18.58	-8.30	.01184

Analysis of Projection

	Proportional	Residual..
OUTPUT1	.000	.000
INPUT1	2.612	.000
INPUT2	6.575	4.119
INPUT3	8.304	.000

Iota:	.69112-EPS(	4.119)	Theta:		.69112
Delta:	.309+EPS(	4.119)	Sigma:	.000+EPS(	4.119)
V-input:	1.000+EPS(	.000)	V-output:	.691+EPS(	-4.119)

Comparison Set:

DEN	.24058	BOS	.11009

DEA REPORT

```
DEA:
NAME: LAS                            MODEL: CRS/I/STA/EPS
Unit:    8                           Number of Units in Analysis:   12
-------------------------------------------------------------------
---------------      DATA      PROJECTED INEFFICIENCY         PRICE
Outputs...
OUTPUT1   (D)       177.81        177.81          .00        .00516
Inputs....
INPUT1    (D)         8.80          8.07         -.73        .07943
INPUT2    (D)        13.95         12.80        -1.15        .02158
INPUT3    (D)        29.54         22.33        -7.21           EPS
-------------------------------------------------------------------

Analysis of Projection------------
          Proportional  Residual..
OUTPUT1           .000        .000
INPUT1            .725        .000
INPUT2           1.149        .000
INPUT3           2.434       4.773
----------------------------------

Iota:     .91760-EPS(      4.773) Theta:                      .91760
Delta:      .082+EPS(      4.773) Sigma:       .000+EPS(      4.773)
V-input:  1.000+EPS(        .000) V-output:    .918+EPS(     -4.773)

Comparison Set:
DEN       .36108         BOS        .05536
```

DEA REPORT

DEA:
NAME: EWR MODEL: CRS/I/STA/EPS
Unit: 9 Number of Units in Analysis: 12

		DATA	PROJECTED	INEFFICIENCY	PRICE
Outputs...					
OUTPUT1	(D)	328.13	328.13	.00	.00208
Inputs....					
INPUT1	(D)	65.64	15.28	-50.36	EPS
INPUT2	(D)	34.36	22.23	-12.13	EPS
INPUT3	(D)	56.57	38.64	-17.93	.01768

Analysis of Projection

	Proportional	Residual..
OUTPUT1	.000	.000
INPUT1	20.803	29.556
INPUT2	10.890	1.239
INPUT3	17.930	.000

Iota:	.68306-EPS(	30.795)	Theta:		.68306
Delta:	.317+EPS(	30.795)	Sigma:	.000+EPS(	30.795)
V-input:	1.000+EPS(	.000)	V-output:	.683+EPS(	-30.795)

Comparison Set:
DEN .71420

DEA REPORT

DEA:
NAME: STL MODEL: CRS/I/STA/EPS
Unit: 10 Number of Units in Analysis: 12

		DATA	PROJECTED	INEFFICIENCY	PRICE
Outputs...					
OUTPUT1	(D)	100.95	100.95	.00	.00800
Inputs....					
INPUT1	(D)	4.39	3.55	-.85	.12523
INPUT2	(D)	14.85	11.09	-3.77	EPS
INPUT3	(D)	24.47	19.75	-4.72	.01838

Analysis of Projection-----------

	Proportional	Residual..
OUTPUT1	.000	.000
INPUT1	.847	.000
INPUT2	2.863	.904
INPUT3	4.716	.000

Iota:	.80725-EPS(	.904)	Theta:		.80725
Delta:	.193+EPS(	.904)	Sigma:	.000+EPS(	.904)
V-input:	1.000+EPS(	.000)	V-output:	.807+EPS(	-.904)

Comparison Set:

DEN	.07347	BOS	.31219

DEA REPORT

```
DEA:
NAME: MSP                               MODEL: CRS/I/STA/EPS
Unit:    11                             Number of Units in Analysis:   12
-----------------------------------------------------------------------
---------------          DATA       PROJECTED INEFFICIENCY        PRICE
Outputs...
OUTPUT1   (D)          104.31          104.31            .00       .00959
Inputs....
INPUT1    (D)            9.04            9.04            .00       .03415
INPUT2    (D)            4.18            4.18            .00       .09996
INPUT3    (D)           26.34           26.34            .00       .01040
-----------------------------------------------------------------------

Iota:                         1.00000 Theta:                      1.00000
Delta:        .000+EPS(         .000) Sigma:       .000+EPS(         .000)
V-input:  1.000+EPS(            .000) V-output:  1.000+EPS(         .000)

Comparison Set:
DEN        .00000          ATL         .00000           MSP       1.00000
```

DEA REPORT

DEA:
NAME: BOS   MODEL: CRS/I/STA/EPS
Unit: 12   Number of Units in Analysis: 12

---------------	DATA	PROJECTED	INEFFICIENCY	PRICE
Outputs...				
OUTPUT1 (D)	215.26	215.26	.00	.00465
Inputs....				
INPUT1 (D)	6.33	6.33	.00	.07276
INPUT2 (D)	28.19	28.19	.00	EPS
INPUT3 (D)	50.53	50.53	.00	.01068

Iota: 1.00000 Theta: 1.00000
Delta: .000+EPS(.000) Sigma: .000+EPS(.000)
V-input: 1.000+EPS(.000) V-output: 1.000+EPS(.000)

Comparison Set:
DEN .00000 BOS 1.00000

INEFFICIENCY CRS/I/STA/EPS

DMU	NAME	OUTPUT1	INPUT1	INPUT2	INPUT3
1	ATL	.00	.00	.00	.00
2	LAX	.00	-.51	-47.28	-2.56
3	SFO	.00	-16.31	-14.26	-35.40
4	MIA	.00	-29.21	-48.51	-79.08
5	DEN	.00	.00	.00	.00
6	JFK	.00	-39.05	-9.36	-19.29
7	PHX	.00	-2.61	-10.69	-8.30
8	LAS	.00	-.73	-1.15	-7.21
9	EWR	.00	-50.36	-12.13	-17.93
10	STL	.00	-.85	-3.77	-4.72
11	MSP	.00	.00	.00	.00
12	BOS	.00	.00	.00	.00

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Environment File : AIRPORTA.DBF

Data base file................................: AIRPORTA.DBF
Number of DMUs in the Reference Set..........: 16
Number of output columns......................: 1
Number of Input columns.......................: 3
Number of Analysis sets.......................: 1

Output field	Type	Scale	Translate
OUTPUT1	OUTPUT-D	1.00	0.00

Input field	Type	Scale	Translate
INPUT1	INPUT--D	1.00	0.00
INPUT2	INPUT--D	1.00	0.00
INPUT3	INPUT--D	1.00	0.00

Reference set condition.......................: All DMUs
Analysis set condition........................: All DMUs
Surface.......................................: CRS
Variant.......................................: Invariant NonArchimedean
Orientation...................................: Input
Convertion....................................: X
ASCII file....................................: AIRPORTA.ASC

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DMU	NAME	EFFICIENCY SCORES IOTA	VRS/I/STA/EPS THETA
1	ATL	1.00000	1.00000
2	LAX	1.00000	1.00000
3	SFO	.49964-EPS(.140)	.49964
4	MIA	.41868-EPS(1.692)	.41868
5	DEN	1.00000	1.00000
6	JFK	1.00000	1.00000
7	PHX	.71227-EPS(4.263)	.71227
8	LAS	.93609-EPS(4.276)	.93609
9	EWR	.68785-EPS(31.052)	.68785
10	STL	.83809-EPS(.955)	.83809
11	MSP	1.00000	1.00000
12	BOS	1.00000	1.00000
13	RDU	1.00000	1.00000
14	ORF	.70246-EPS(.140)	.70246
15	RIC	1.00000	1.00000
16	ROA	1.00000	1.00000

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DMU	NAME	DISTANCE MEASURES DELTA		VRS/I/STA/EPS SIGMA	
1	ATL	.000+EPS(	.000)	.000+EPS(	.000)
2	LAX	.000+EPS(	.000)	.000+EPS(	.000)
3	SFO	.500+EPS(	.140)	.000+EPS(	.140)
4	MIA	.581+EPS(	1.692)	.000+EPS(	1.692)
5	DEN	.000+EPS(	.000)	.000+EPS(	.000)
6	JFK	.000+EPS(	.000)	.000+EPS(	.000)
7	PHX	.288+EPS(	4.263)	.000+EPS(	4.263)
8	LAS	.064+EPS(	4.276)	.000+EPS(	4.276)
9	EWR	.312+EPS(	31.052)	.000+EPS(	31.052)
10	STL	.162+EPS(	.955)	.000+EPS(	.955)
11	MSP	.000+EPS(	.000)	.000+EPS(	.000)
12	BOS	.000+EPS(	.000)	.000+EPS(	.000)
13	RDU	.000+EPS(	.000)	.000+EPS(	.000)
14	ORF	.298+EPS(	.140)	.000+EPS(	.140)
15	RIC	.000+EPS(	.000)	.000+EPS(	.000)
16	ROA	.000+EPS(	.000)	.000+EPS(	.000)

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DMU	NAME	XI	VIRTUAL I/O	CHI	VRS/I/STA/EPS	OMEGA
1	ATL	1.000	.983+EPS(	5.348)	.017+EPS(	-5.348)
2	LAX	1.000	1.116+EPS(	141.181)	-.116+EPS(	-141.181)
3	SFO	1.000	.565+EPS(	-29.708)	-.066+EPS(	29.568)
4	MIA	1.000	.537+EPS(	-53.995)	-.118+EPS(	52.303)
5	DEN	1.000	.983+EPS(	.120)	.017+EPS(	-.120)
6	JFK	1.000	2.954+EPS(	162.984)	-1.954+EPS(	-162.984)
7	PHX	1.000	.680+EPS(	-4.041)	.033+EPS(	-.222)
8	LAS	1.000	.904+EPS(	-4.107)	.032+EPS(	-.168)
9	EWR	1.000	.671+EPS(	-30.150)	.017+EPS(	-.902)
10	STL	1.000	.788+EPS(	-.871)	.050+EPS(	-.083)
11	MSP	1.000	1.163+EPS(	.000)	-.163+EPS(	.000)
12	BOS	1.000	.971+EPS(	.000)	.029+EPS(	.000)
13	RDU	1.000	.800+EPS(	.097)	.200+EPS(	-.097)
14	ORF	1.000	.496+EPS(	-.079)	.206+EPS(	-.061)
15	RIC	1.000	.745+EPS(	.000)	.255+EPS(	.000)
16	ROA	1.000	.394+EPS(	.048)	.606+EPS(	-.048)

SLACK AND EXCESS VRS/I/STA/EPS

DMU	NAME	OUTPUT1	INPUT1	INPUT2	INPUT3
1	ATL	.00	.00	.00	.00
2	LAX	.00	.00	.00	.00
3	SFO	.00	.00	.00	.14
4	MIA	.00	.00	.00	1.69
5	DEN	.00	.00	.00	.00
6	JFK	.00	.00	.00	.00
7	PHX	.00	.00	4.26	.00
8	LAS	.00	.00	.00	4.28
9	EWR	.00	29.80	1.26	.00
10	STL	.00	.00	.95	.00
11	MSP	.00	.00	.00	.00
12	BOS	.00	.00	.00	.00
13	RDU	.00	.00	.00	.00
14	ORF	.00	.00	.14	.00
15	RIC	.00	.00	.00	.00
16	ROA	.00	.00	.00	.00

PRICES (MULTIPLIERS) VRS/I/STA/EPS

DMU	NAME	OUTPUT1	INPUT1	INPUT2	INPUT3
1	ATL	.00566	EPS	.03130	.03041
2	LAX	.00304	.04818	EPS	.00461
3	SFO	.00231	.00679	.02734	EPS
4	MIA	.00119	.01911	.00058	EPS
5	DEN	.00214	EPS	.00880	.01342
6	JFK	.00564	EPS	EPS	.01176
7	PHX	.00506	.07915	EPS	.01231
8	LAS	.00508	.07768	.02268	EPS
9	EWR	.00205	EPS	EPS	.01768
10	STL	.00780	.12198	EPS	.01897
11	MSP	.01115	.03613	.12430	.00586
12	BOS	.00451	.06930	.01926	.00037
13	RDU	.02476	EPS	.10183	.15534
14	ORF	.03206	.50111	EPS	.07791
15	RIC	.04039	.62020	.17236	.00329
16	ROA	.07525	EPS	.30949	.47214

DEA REPORT

DEA:
NAME: ATL — MODEL: VRS/I/STA/EPS
Unit: 1 — Number of Units in Analysis: 16

		DATA	PROJECTED	INEFFICIENCY	PRICE
Outputs...					
OUTPUT1	(D)	173.50	173.50	.00	.00566
Inputs....					
INPUT1	(D)	18.89	18.89	.00	EPS
INPUT2	(D)	7.58	7.58	.00	.03130
INPUT3	(D)	25.08	25.08	.00	.03041

Iota:		1.00000	Theta:		1.00000
Delta:	.000+EPS(	.000)	Sigma:	.000+EPS(	.000)
V-input:	1.000+EPS(	.000)	V-output:	.983+EPS(	5.348)
Omega:	.017+EPS(	-5.348)			

Comparison Set:

ATL	1.00000	RDU	.00000	DEN	.00000

DEA REPORT

```
DEA:
NAME: LAX                            MODEL: VRS/I/STA/EPS
Unit:    2                           Number of Units in Analysis:   16
------------------------------------------------------------------
---------------          DATA     PROJECTED INEFFICIENCY      PRICE
Outputs...
OUTPUT1  (D)           367.24        367.24          .00     .00304
Inputs....
INPUT1   (D)            14.04         14.04          .00     .04818
INPUT2   (D)            85.31         85.31          .00        EPS
INPUT3   (D)            70.14         70.14          .00     .00461
------------------------------------------------------------------

Iota:                          1.00000 Theta:                 1.00000
Delta:      .000+EPS(            .000) Sigma:     .000+EPS(      .000)
V-input:  1.000+EPS(            .000) V-output: 1.116+EPS(   141.181)
Omega:    -.116+EPS(        -141.181)
Comparison Set:
LAX        1.00000          BOS         .00000        DEN       .00000
```

DEA REPORT

DEA:
NAME: SFO — MODEL: VRS/I/STA/EPS
Unit: 3 — Number of Units in Analysis: 16

		DATA	PROJECTED	INEFFICIENCY	PRICE
Outputs...					
OUTPUT1	(D)	244.50	244.50	.00	.00231
Inputs....					
INPUT1	(D)	32.58	16.28	-16.30	.00679
INPUT2	(D)	28.48	14.23	-14.25	.02734
INPUT3	(D)	70.70	35.18	-35.52	EPS

Analysis of Projection-----------

	Proportional	Residual..
OUTPUT1	.000	.000
INPUT1	16.302	.000
INPUT2	14.250	.000
INPUT3	35.376	.140

Iota:	.49964-EPS(	.140)	Theta:		.49964
Delta:	.500+EPS(	.140)	Sigma:	.000+EPS(	.140)
V-input:	1.000+EPS(	.000)	V-output:	.565+EPS(	-29.708)
Omega:	-.066+EPS(	29.568)			

Comparison Set:

MSP	.34961	ATL	.31746	DEN	.33293

DEA REPORT

DEA:
NAME: MIA MODEL: VRS/I/STA/EPS
Unit: 4 Number of Units in Analysis: 16

		DATA	PROJECTED	INEFFICIENCY	PRICE
Outputs...					
OUTPUT1	(D)	452.61	452.61	.00	.00119
Inputs....					
INPUT1	(D)	49.90	20.89	-29.01	.01911
INPUT2	(D)	80.63	33.76	-46.87	.00058
INPUT3	(D)	135.07	54.86	-80.21	EPS

Analysis of Projection

	Proportional	Residual..
OUTPUT1	.000	.000
INPUT1	29.006	.000
INPUT2	46.871	.000
INPUT3	78.517	1.692

Iota:	.41868-EPS(	1.692)	Theta:		.41868
Delta:	.581+EPS(	1.692)	Sigma:	.000+EPS(	1.692)
V-input:	1.000+EPS(	.000)	V-output:	.537+EPS(	-53.995)
Omega:	-.118+EPS(	52.303)			

Comparison Set:

LAX	.04904	BOS	.00942	DEN	.94155

DEA REPORT

DEA:
NAME: DEN
MODEL: VRS/I/STA/EPS
Unit: 5
Number of Units in Analysis: 16

		DATA	PROJECTED	INEFFICIENCY	PRICE
Outputs...					
OUTPUT1	(D)	459.43	459.43	.00	.00214
Inputs....					
INPUT1	(D)	21.39	21.39	.00	EPS
INPUT2	(D)	31.13	31.13	.00	.00880
INPUT3	(D)	54.11	54.11	.00	.01342

Iota: 1.00000 Theta: 1.00000
Delta: .000+EPS(.000) Sigma: .000+EPS(.000)
V-input: 1.000+EPS(.000) V-output: .983+EPS(.120)
Omega: .017+EPS(-.120)
Comparison Set:
DEN 1.00000 RDU .00000 ROA .00000

DEA REPORT

```
DEA:
NAME: JFK                             MODEL: VRS/I/STA/EPS
Unit:     6                           Number of Units in Analysis:   16
-----------------------------------------------------------------------
---------------         DATA      PROJECTED INEFFICIENCY         PRICE
Outputs...
OUTPUT1   (D)         523.90         523.90          .00        .00564
Inputs....
INPUT1    (D)          72.79          72.79          .00           EPS
INPUT2    (D)          41.25          41.25          .00           EPS
INPUT3    (D)          85.01          85.01          .00        .01176
-----------------------------------------------------------------------

Iota:                      1.00000 Theta:                      1.00000
Delta:      .000+EPS(         .000) Sigma:      .000+EPS(        .000)
V-input:  1.000+EPS(         .000) V-output:  2.954+EPS(    162.984)
Omega:   -1.954+EPS(    -162.984)
Comparison Set:
JFK       1.00000          DEN          .00000
```

DEA REPORT

DEA:
NAME: PHX — MODEL: VRS/I/STA/EPS
Unit: 7 — Number of Units in Analysis: 16

	DATA	PROJECTED	INEFFICIENCY	PRICE
Outputs...				
OUTPUT1 (D)	134.23	134.23	.00	.00506
Inputs....				
INPUT1 (D)	8.45	6.02	-2.43	.07915
INPUT2 (D)	21.29	10.90	-10.39	EPS
INPUT3 (D)	26.88	19.15	-7.74	.01231

Analysis of Projection-----------

	Proportional	Residual..
OUTPUT1	.000	.000
INPUT1	2.433	.000
INPUT2	6.125	4.263
INPUT3	7.735	.000

Iota:	.71227-EPS(	4.263)	Theta:		.71227
Delta:	.288+EPS(	4.263)	Sigma:	.000+EPS(	4.263)
V-input:	1.000+EPS(	.000)	V-output:	.680+EPS(	-4.041)
Omega:	.033+EPS(	-.222)			

Comparison Set:

BOS	.10816	ROA	.65785	DEN	.23399

DEA REPORT

```
DEA:
NAME: LAS                               MODEL: VRS/I/STA/EPS
Unit:    8                              Number of Units in Analysis:   16
---------------------------------------------------------------------
---------------      DATA      PROJECTED INEFFICIENCY          PRICE
Outputs...
OUTPUT1  (D)       177.81        177.81            .00        .00508
Inputs....
INPUT1   (D)         8.80          8.24           -.56        .07768
INPUT2   (D)        13.95         13.06           -.89        .02268
INPUT3   (D)        29.54         23.38          -6.16           EPS
---------------------------------------------------------------------

Analysis of Projection-----------
          Proportional  Residual..
OUTPUT1           .000        .000
INPUT1            .562        .000
INPUT2            .891        .000
INPUT3           1.888       4.276
----------------------------------

Iota:     .93609-EPS(      4.276) Theta:                       .93609
Delta:      .064+EPS(      4.276) Sigma:     .000+EPS(        4.276)
V-input:  1.000+EPS(        .000) V-output:  .904+EPS(       -4.107)
Omega:      .032+EPS(      -.168)
Comparison Set:
RIC         .60291      ROA       .03467       DEN            .36242
```

DEA REPORT

```
DEA:
NAME: EWR                                MODEL: VRS/I/STA/EPS
Unit:    9                               Number of Units in Analysis:   16
---------------------------------------------------------------------------
---------------          DATA        PROJECTED INEFFICIENCY         PRICE
Outputs...
OUTPUT1   (D)          328.13          328.13           .00        .00205
Inputs....
INPUT1    (D)           65.64           15.35        -50.28           EPS
INPUT2    (D)           34.36           22.38        -11.98           EPS
INPUT3    (D)           56.57           38.91        -17.66        .01768
---------------------------------------------------------------------------

Analysis of Projection------------
           Proportional  Residual..
OUTPUT1            .000        .000
INPUT1           20.489      29.795
INPUT2           10.726       1.257
INPUT3           17.659        .000
----------------------------------

Iota:     .68785-EPS(      31.052) Theta:                         .68785
Delta:      .312+EPS(      31.052) Sigma:      .000+EPS(      31.052)
V-input:  1.000+EPS(         .000) V-output:    .671+EPS(     -30.150)
Omega:      .017+EPS(       -.902)
Comparison Set:
DEN          .71091        ROA         .28909
```

DEA REPORT

```
DEA:
NAME: STL                                MODEL: VRS/I/STA/EPS
Unit:   10                               Number of Units in Analysis:   16
-----------------------------------------------------------------------
---------------          DATA      PROJECTED INEFFICIENCY          PRICE
Outputs...
OUTPUT1   (D)          100.95         100.95            .00         .00780
Inputs....
INPUT1    (D)            4.39           3.68           -.71         .12198
INPUT2    (D)           14.85          11.49          -3.36            EPS
INPUT3    (D)           24.47          20.51          -3.96         .01897
-----------------------------------------------------------------------

Analysis of Projection-----------
          Proportional  Residual..
OUTPUT1           .000        .000
INPUT1            .711        .000
INPUT2           2.405        .955
INPUT3           3.961        .000
----------------------------------

Iota:     .83809-EPS(        .955) Theta:                         .83809
Delta:      .162+EPS(        .955) Sigma:         .000+EPS(        .955)
V-input:  1.000+EPS(         .000) V-output:      .788+EPS(       -.871)
Omega:      .050+EPS(       -.083)
Comparison Set:
ROA         .61768         DEN         .06318          BOS         .31915
```

DEA REPORT

DEA:
NAME: MSP — MODEL: VRS/I/STA/EPS
Unit: 11 — Number of Units in Analysis: 16

		DATA	PROJECTED	INEFFICIENCY	PRICE
Outputs...					
OUTPUT1	(D)	104.31	104.31	.00	.01115
Inputs....					
INPUT1	(D)	9.04	9.04	.00	.03613
INPUT2	(D)	4.18	4.18	.00	.12430
INPUT3	(D)	26.34	26.34	.00	.00586

Iota:		1.00000	Theta:		1.00000
Delta:	.000+EPS(	.000)	Sigma:	.000+EPS(	.000)
V-input:	1.000+EPS(	.000)	V-output:	1.163+EPS(	.000)
Omega:	-.163+EPS(	.000)			

Comparison Set:

MSP	1.00000	ATL	.00000	RDU	.00000
DEN	.00000				

DEA REPORT

DEA:
NAME: BOS — MODEL: VRS/I/STA/EPS
Unit: 12 — Number of Units in Analysis: 16

---------------	DATA	PROJECTED	INEFFICIENCY	PRICE
Outputs...				
OUTPUT1 (D)	215.26	215.26	.00	.00451
Inputs....				
INPUT1 (D)	6.33	6.33	.00	.06930
INPUT2 (D)	28.19	28.19	.00	.01926
INPUT3 (D)	50.53	50.53	.00	.00037

Iota:		1.00000	Theta:		1.00000
Delta:	.000+EPS(	.000)	Sigma:	.000+EPS(	.000)
V-input:	1.000+EPS(	.000)	V-output:	.971+EPS(	.000)
Omega:	.029+EPS(	.000)			

Comparison Set:

BOS	1.00000	DEN	.00000	RIC	.00000
ROA	.00000				

DEA REPORT

DEA:
NAME: RDU — MODEL: VRS/I/STA/EPS
Unit: 13 — Number of Units in Analysis: 16

	DATA	PROJECTED	INEFFICIENCY	PRICE
Outputs...				
OUTPUT1 (D)	32.33	32.33	.00	.02476
Inputs....				
INPUT1 (D)	3.10	3.10	.00	EPS
INPUT2 (D)	.40	.40	.00	.10183
INPUT3 (D)	6.18	6.18	.00	.15534

Iota:		1.00000	Theta:	1.00000
Delta:	.000+EPS(	.000)	Sigma: .000+EPS(	.000)
V-input:	1.000+EPS(	.000)	V-output: .800+EPS(	.097)
Omega:	.200+EPS(	-.097)		

Comparison Set:

RDU	1.00000	ROA	.00000	DEN	.00000		

DEA REPORT

DEA:
NAME: ORF — MODEL: VRS/I/STA/EPS
Unit: 14 — Number of Units in Analysis: 16

---------------	DATA	PROJECTED	INEFFICIENCY	PRICE
Outputs...				
OUTPUT1 (D)	15.48	15.48	.00	.03206
Inputs....				
INPUT1 (D)	1.20	.84	-.36	.50111
INPUT2 (D)	3.07	2.01	-1.05	EPS
INPUT3 (D)	5.14	3.61	-1.53	.07791

Analysis of Projection-----------

	Proportional	Residual..
OUTPUT1	.000	.000
INPUT1	.356	.000
INPUT2	.913	.140
INPUT3	1.530	.000

Iota:	.70246-EPS(.140)	Theta:		.70246
Delta:	.298+EPS(.140)	Sigma:	.000+EPS(	.140)
V-input:	1.000+EPS(.000)	V-output:	.496+EPS(	-.079)
Omega:	.206+EPS(-.061)			

Comparison Set:

BOS	.03539	ROA	.95842	DEN	.00620

DEA REPORT

DEA:
NAME: RIC　　MODEL: VRS/I/STA/EPS
Unit: 15　　Number of Units in Analysis: 16

---------------	DATA	PROJECTED	INEFFICIENCY	PRICE
Outputs...				
OUTPUT1 (D)	18.44	18.44	.00	.04039
Inputs....				
INPUT1 (D)	.77	.77	.00	.62020
INPUT2 (D)	2.90	2.90	.00	.17236
INPUT3 (D)	6.16	6.16	.00	.00329

Iota: 1.00000 Theta: 1.00000
Delta: .000+EPS(.000) Sigma: .000+EPS(.000)
V-input: 1.000+EPS(.000) V-output: .745+EPS(.000)
Omega: .255+EPS(.000)
Comparison Set:

RIC	1.00000	DEN	.00000	ROA	.00000
BOS	.00000				

DEA REPORT

DEA:
NAME: ROA — MODEL: VRS/I/STA/EPS
Unit: 16 — Number of Units in Analysis: 16

	DATA	PROJECTED	INEFFICIENCY	PRICE
Outputs...				
OUTPUT1 (D)	5.23	5.23	.00	.07525
Inputs....				
INPUT1 (D)	.50	.50	.00	EPS
INPUT2 (D)	.86	.86	.00	.30949
INPUT3 (D)	1.55	1.55	.00	.47214

Iota: 1.00000 Theta: 1.00000
Delta: .000+EPS(.000) Sigma: .000+EPS(.000)
V-input: 1.000+EPS(.000) V-output: .394+EPS(.048)
Omega: .606+EPS(-.048)
Comparison Set:

RDU	.00000	ROA	1.00000	DEN	.00000

INEFFICIENCY VRS/I/STA/EPS

DMU	NAME	OUTPUT1	INPUT1	INPUT2	INPUT3
1	ATL	.00	.00	.00	.00
2	LAX	.00	.00	.00	.00
3	SFO	.00	-16.30	-14.25	-35.52
4	MIA	.00	-29.01	-46.87	-80.21
5	DEN	.00	.00	.00	.00
6	JFK	.00	.00	.00	.00
7	PHX	.00	-2.43	-10.39	-7.74
8	LAS	.00	-.56	-.89	-6.16
9	EWR	.00	-50.28	-11.98	-17.66
10	STL	.00	-.71	-3.36	-3.96
11	MSP	.00	.00	.00	.00
12	BOS	.00	.00	.00	.00
13	RDU	.00	.00	.00	.00
14	ORF	.00	-.36	-1.05	-1.53
15	RIC	.00	.00	.00	.00
16	ROA	.00	.00	.00	.00

VITA

Scott A. Cummings was born in Knoxville Tennessee on 9 July 1957. He moved to the Hampton Roads area in 1959 and has resided there ever since. He graduated from Tidewater Community College, where he received an A.S. in General Studies in 1978. In 1982 he graduated from Old Dominion University's School Of Engineering. While at Old Dominion University he participated in the Cooperative Education Program (COOP), and worked for the Combatant Craft Department, under the Naval Sea Systems Command. Here he was assigned to the Test and Evaluation (T&E) branch where he assisted senior engineers in the testing of several Navy Combatants. After graduating, he accepted a position with NKF Engineering Inc., and was responsible for the development of their Computer Aided Design Section. He was with NKF for seven years, and in 1989 took a position with the Combatant Craft Department, which is currently under the Naval Surface Warfare Center, Carderock Division. His duties were to develop specialized systems for Navy small combatants. After a couple of years he was promoted, and is now the acting branch head for the Special Projects Branch. He oversees the development of advanced R&D projects within the Combatant Craft Department. While in this position, he competed and was accepted into a long term training program that allowed him to pursue his Masters degree, and eventually work towards his Ph.D.

Degrees and Honors :

Associate In Science, General Studies; Tidewater Community College, 1978

Bachelors in Mechanical Engineering Tech, Old Dominion University, 1982

Masters in Science, Engineering Management, Old Dominion University, 1998

Letters of Accommodation, Naval Sea Systems Command, (1989-1995)

Department of the Navy, NAVSEA Medallion, Naval Sea Systems Command, (1995)

Memberships and Papers:

Society of Naval Architects (SNAME)

American Society of Naval Engineers (ASNE)

Computer Aided Design Techniques in small craft, SNAME

Computer Aided Optimization Methods, ASNE

Evaluation of Airport Operating Efficiencies Using Data Envelopment Analysis, ASEM