TRANSPORT MANAGEMENT STUDIES IN NIGERIA

A QUANTITATIVE MODELLING APPROACH

FESTSCHRIFT IN HONOUR OF
PROFESSOR INNOCENT CHUKA OGWUDE

$$\sum_{i=1}^{n} \lambda_j y_{ri} \geq y_{j\,;}\ r = 1, \ldots \ldots, R$$

$$\sum_{i=1}^{n} \lambda_i x_{si}, \leq \theta_{j\,;} x_{j\,;}\ s = 1, \ldots \ldots, S$$

$$\lambda_i \geq 0;\ \forall_i$$

Edited by

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DEDICATION

To Professor Innocent Chukwuka Ogwude

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AIRPORT EFFICIENCY IN NIGERIA: A DATA ENVELOPMENT ANALYSIS APPROACH

Nwaogbe, O.R.[†], *Okeudo, G.N., Abraham Pius, Adindu, C.C., and Diugwu, I.A.*

Introduction

The global investment expansion in African countries has led Nigeria, Africa's largest economy, to work towards development of her transport infrastructure projects, especially the aviation industry to accommodate its surging traffic at the airports. The scope of Nigeria's transport infrastructure project development includes international and domestic airports. Nigeria aims towards being the hub of aviation business for the West Africa subregion and the African continent at large. Consequently, the Nigerian government and her transport industry professionals and other aviation industry stakeholders have recently become interested in evaluating the overall performance, productivity and efficiency of the nations' aviation industry. The role of air transportation in Nigeria is significant owing to a lack of a competitor in terms of speed and safety and in the aspects of direct passenger and cargo transportation all around the country's entire region. This, therefore, makes passenger and freight transportation very difficult. The aviation industry is a very important sector of a nations' overall transport infrastructure project that is highly needed in the social, tourism and economic development of the country (Nwaogbe, Ogwude and Ibe 2017).

Global changes in the air transport industry coupled with poor funding due to economic downturn in the region, triggered infrastructure degeneration. It became apparent that the states lack supervisory capabilities to manage airports successfully (Nwaogbe et al. 2017). The current trend in most developed countries is inadequate government regulation and involvement in airport operations. Another is the desire to relax and provide a business environment where the private sector can operate and offer the necessary impetus for change and stability as needed by the industry to compete at the international level. Liberalization of airport operation within the region, promotes flexibility, competence and

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professionalism (Nwaogbe et al. 2015). It guarantees a better service experience and loyalty/repeat purchases, for the sector long-term development and sustainability (Pius, Nwaogbe and Mania 2017).

Many studies have been conducted in Nigeria on air transportation, airport capacity utilization performance and efficiency in order to make suggestions on how to increase airport and aviation performance. But much work need to be done in the country on the aspect of airport productivity, airport competition, airport quality of service and other operational efficiency factors to enable the airport operators/management, airlines and government to benchmark their airport operational activities. Through this process, the government would go a long way in developing its airport infrastructure and her human resources in order to achieve their goal of being the hub airport of Africa.

The aviation industry is one of the major important sectors in the transportation industry in the world. Its continuous development and technological service improvement makes the sector a major contributor to modern and global standard of advanced development in the transportation sector. The growth of this sector cannot be compared to any other major transport sector due to its sophisticated technological equipment and continuous innovation. With the help of this sector, much have been achieved globally in terms of economic development, tourism, connectivity, logistics and supply chain activities. The demand of transport services has greatly increased the influence of the aviation sector in most countries as well as their global economies. It has enhanced rapid movement of passengers, goods and services to the domestic and international markets of the air transport sector. The industry plays a major role in the country and in the world in the aspect of work and leisure, improved quality of life and standard of living of the people, economic growth, creation of employment opportunities, and increased revenue through tax. All these are generated through supply chain transformation from the airport to the airlines that operate the transport services (Nwaogbe et al. 2013).

With respect to the high growth rate of Nigeria's population and high traffic growth of domestic and international demand due to high economic development of the country and its position as the giant of Africa, the study will significantly reposition the aviation transport sector (Nwaogbe 2018). Furthermore, various airport infrastructural challenges and sophisticated equipment for safety and security, traffic congestions, delays of flight have over time given rise to significant deterioration in the airports in terms of drawback on passenger throughput, revenue and other airport outputs. The focus of this study on airport productivity would help to examine the relationship between inputs (runway dimension, terminal capacity, number of employees, total assets, and total cost) and outputs (passenger throughput and aircraft movement) of airport operation in Nigeria (Nwaogbe et al. 2017; Nwaogbe et al. 2018).

Justification and Significance of Study

The study would help airport managers including the Federal Airport Authority of Nigeria (FAAN) to easily determine the probability of the general traffic level (outputs) that exists at all the airports in the country and how to accommodate them at a given level of input. It would be very useful in accessing, monitoring, managing as well as planning all other operational activities at various airports in the country. Furthermore, the assessment allows or helps the airports directors of operations, managers of operations to benchmark their operational performance or activities, and how to set up appropriate standards on their targeted outputs and their improvement in the airport businesses and activities, to generate more output or maximize the management and the Federal Government objectives for setting up the airports.

Airport performance is usually analyzed in terms of efficiency or productivity. DEA models (Gillen and Lall 1997; Gillen and Lall 2001; Adler and Berechman 2001; Barros and Dieke 2007; Barros, Managi and Yoshida 2011) and SFA stochastic frontier models are usually adopted (Barros and Sampaio 2004; Barros 2008a; Barros 2009; Diana 2010). However, European and American airports are usually analysed, while African airports are rarely analysed (Barros and Marques 2010). This paper, therefore contributes to airport efficiency by analysing Nigerian airports, using a DEA model. The motivation for this research is its pioneer status in the analysis of Nigerian airports, using a DEA model. The analysis of airport efficiency can yield significant insights into the competitiveness of airports and their potential for increasing productivity and improving resource use (Biesebroeck 2007). The research on airports has adopted DEA models (Sarkis 2000; Sarkis and Tallury 2004) or homogenous production frontier models (Pels et al. 2001, 2003).

Contextual Setting

With the oil boom era of the 1970s the need for more airports became apparent. The major criterion for locating the new airports seemed to be the desire of the government to open up corners of the country to access development. Towards the realization of this goal, government appeared to be pursuing a policy of one airport, for each state capital. Thus, as more states were created more airports were built, until cost consideration curtailed the construction of any more airports. Currently Nigeria has a total of twenty-five airports, five of which are international, while the rest operate domestic routes. There is also an aviation training school located in Zaria. Two of the original three aerodromes had in the course of time developed into international airports. One of these was the Murtala Muhammed Airport in Lagos which was, until 1991, the seat of government. The other was Aminu Kano Airport in Kano, whose selection for upgrading must have been based on the fact that Kano is a commercial hub. Similar reasons appear to inform subsequent development of the three additional international airports at Kaduna, Port Harcourt and Abuja. The previous two cities have high volumes of commercial activities while Abuja is the new Federal Capital (Barros and Ibiwoye 2012).

The airports are managed by the Federal Airports Authority of Nigeria (FAAN) on behalf of the Federal Government of Nigeria which owns the facilities. FAAN was established in 1995 to carry out the functions of two erstwhile organizations, the Nigerian Airports Authority (NAA) and the Federal Civil Aviation Authority (FCAA). However, the need to conform to International Civil Aviation Organization's (ICAO) requirement led to another restructuring in 1999. Since ICAO stipulates the separation of regulatory bodies from service providers, it became imperative for all affiliates to establish a state organization that would ensure compliance with air navigations. This led to the creation of a fully autonomous Nigerian Civil Aviation Authority (NCAA) in 1999 (Balogun 2008).

The aviation sector in Nigeria comprises 25 airports, under the authority of Federal Airport Authority of Nigeria (FAAN). Among these, five are classified by FAAN as international airports (scheduled for international flights), while the remaining 19 airports are taken as domestic airports (scheduled for domestic flights). The airports operating with a commercial objective are 24 while one airport is being managed by the private industry (Shell Petroleum Development Company Limited). Among the 24 commercial airports, one terminal of the Murtala Muhammed Airport Lagos is controlled by a private sector under government agreement of the public private partnership policy. The terminal is concessioned while the other airports and their terminals are controlled by the Federal Government under the Federal Ministry of Aviation. The infrastructures that are used at the airports are provided by the Federal Government.

Murtala Muhammed International Airport is Nigeria's major airport with the highest aviation operations. As a hub airport for intercontinental passenger traffic, the airport can offer Nigerian residents and businesses a better offer in terms of access to their various destinations, at a higher frequency and at lower price in terms of fare charges. With such hub and spoke network, its benefits will enhance the nations various air transport connectivity systems. This tendency contributes to high global, and nations' overall international trade and economic levels of productivity and Gross Domestic Product of Nigeria (Nwaogbe et al. 2013).

With the above background report on the aviation industry in Nigeria, the airports must take cognizance of general national concerns regarding their operations, more especially on the aspect of safety and security of their passengers and their businesses in order to achieve the desired productivity and efficiency. Nigerian airports are distributed all over the country and comprise international, regional, and state airports.

Productivity and Efficiency Concepts

Data Envelopment Analysis (DEA) is a Linear Programming based technique for evaluating apparent efficiency levels within a group of organizations. The efficiency of an organization is calculated relative to the group's observed best practice. DEA tries to look at various efficiency concepts. The most common efficiency concept is 'technical efficiency' (Bhagavath 2006).

Productivity

These measures are closely related/ overlapping measures of an airport's performance. They are sometimes separated into productivity measures, which track output on a non-cost basis,. e.g. passengers per airport employee or departures per gate; as well as efficiency measures that track output on a cost basis e.g., total or operating cost per passenger. Lovell (1993) defines the productivity of a production unit as 'the ratio of its output to its input'. This ratio is easy to compute if the unit uses a single input to produce a single output. On the contrary, if the production unit uses several inputs to produce several outputs, then the inputs and outputs have to be aggregated so that productivity remains the ratio of the two scales. We can distinguish between 'partial productivity'; when it concerns a sole production factor, and 'total factor' (global productivity), when referring to all (every) factors. Similarly, in the concept of efficiency, many authors do not make any difference between productivity and efficiency. For instance, Sengupta (1995) and Cooper, Seiford & Tone (2000) define both productivity and efficiency as the ratio between output and input.

Productivity of a production unit is defined as the ratio of its outputs to its inputs (both aggregated in some economically sensible way). Productivity varies due to differences in production technology, differences in the efficiency of the production process, and differences in the environment in which the production occurs (Reiff, Sugár and Surányi 2002). Productivity is commonly defined as a ratio of a volume measure of output to a volume measure of input. While there is no disagreement on this general notion, a look at the productivity literature and its various applications reveals that there is neither a unique purpose for, nor a single measure of productivity. More so, the relevant productivity measures are expressed in physical units (e.g. cars per day, passenger-miles per person, passenger per terminal seat, passenger per labour etc.) and often very specific.

Objectives of Productivity Measurement

Efficiency: Efficiency is defined as the measure of effectiveness that produces the minimum waste of time, effort, and skill. It is the success with which an organization uses its resources to produce outputs—that is the degree to which the observed use of resources to produce outputs of a given quality matches the optimal use of resources to produce outputs of the given quality. This can be assessed in terms of technical, allocative, cost and dynamic efficiency. Improving the performance of an organizational unit relies on both efficiency and effectiveness. A government service provider might increase its measured efficiency at the expense of the effectiveness of its service. For example, an air transport organization might reduce the inputs used like fleet size, cost, aircraft or day to carry the same number of passengers. This could increase the apparent efficiency of that air transport organization but reduce its effectiveness in providing satisfactory outcomes for passengers. Therefore, it is also important to develop effectiveness indicators (Bhagavath 2006).

The quest for identifying changes in efficiency is conceptually different from identifying technical change. Full efficiency in an engineering sense means that a production process has achieved the maximum amount of output that is physically achievable with current technology, and given a fixed amount of inputs (Diewert and Lawrence 1999).

Efficiency of a production unit is the relation of the observed and optimal values of inputs and outputs. The ratio can be compared as the observed to maximum possible output obtainable from the given set of inputs, or the ratio of the minimum possible amount of inputs to the observed required to produce the given output (Reiff et al. 2002). Technical efficiency gains are thus a movement towards "best practice", or the elimination of technical and organizational inefficiencies. Not every form of technical efficiency makes economic sense, and this is captured by the notion of allocative efficiency, which implies profit-maximizing behaviour on the side of the firm (Charnes, Cooper, Lewin and Seiford 1994; Diewert and Mendoza 1995). One notes that when productivity measurement concerns the industry level, efficiency gains can either be due to improved efficiency in individual establishments that make up the industry or to a shift of production towards more efficient establishments.

Instead of defining the efficiency as the ratio between outputs and inputs, we can describe it as a distance between the quantity of input and output, and the quantity of input and output that defines a frontier, the best possible frontier for a firm in its cluster (industry). Efficiency and productivity, anyway, are two cooperating concepts. The measures of efficiency are more accurate than those of productivity in the sense that they involve a comparison with the most efficient frontier, and for that they can compete with those productivity measures that are based on the ratio of outputs on inputs. Lovell (1993) defines the efficiency of a production unit in terms of a comparison between observed and optimal values of its output and input. The comparison can take the form of the ratio of observed to maximum potential output obtainable from the given input, or the ratio of minimum potential to observed input required to produce the given output. In these two comparisons the optimum is defined in terms of production capacity and technical efficiency.

Technical Efficiency: It is the conversion of physical inputs (such as the services of employees and machines etc.) into outputs relative to best practice. In other words, given current technology, there is no wastage of inputs whatsoever in producing the given quantity of output. An organization supposedly operating at best practice is said to be 100% technically efficient. If operating below best practice levels, then the organization's technical efficiency is expressed as a percentage of best practice. Managerial practices and the scale or size of operations affect technical efficiency, which is based on engineering relationships but not on prices and costs. Koopmans (1951) provided a definition of what we refer to as technical efficiency: an input-output vector is technically efficient if, and only if, increasing any output or decreasing any input is possible only by decreasing some other output or increasing some other input.

Allocative Efficiency: This refers to whether inputs for a given level of output and set of input prices are chosen to minimize the cost of production, assuming that the organization being examined is already fully technically efficient. Allocative efficiency is also expressed as a percentage score, with a score of 100% indicating that the organization is using its inputs in the proportions that would minimize costs. An organization that is operating at best practice in engineering terms could still be allocative inefficient because it is not using inputs in the proportions which minimize its costs, given relative input prices. Allocative efficiency is also another important concept in the context of production economics. Unlike technical and scale efficiencies, which only consider physical quantities and technical relationships and do not address issues such as costs or profits, allocative efficiency studies the costs of production given that the information on prices and a behavioural assumption such as cost minimization or profit maximization is properly established. For instance, allocative efficiency in input selection occurs when a selection of inputs (e.g. materials, labour and capital) produces a given quantity of output at minimum cost given the prevailing input prices (Coelli, Prasada Rao and Battese 1998).

Cost Efficiency: This refers to the combination of technical and allocative efficiency. An organization would only be cost efficient if it is both technically and allocative efficient. Cost efficiency is calculated as the product of the technical and allocative efficiency scores (expressed as a percentage), so an organization can only achieve a 100% score in cost efficiency if it has achieved 100% in both technical and allocative efficiency (Bhagavath 2006).

Scale Efficiency: Scale efficiency is the ratio (proportion) of technical efficiency to pure technical efficiency. A unit is said to be scale efficient when its size of operations is optimal so that any modifications on its size would render the unit less efficient. The value of scale efficiency is obtained by dividing the aggregate efficiency by the technical efficiency (Coelli, Prasada Rao, O'Daniel and Battese 2005). Scale efficiency can be easily obtained, using the ratio of technical efficiency scores of two specifications. So many literatures on airport benchmarking have given a great attention to the scale of airport operations and generally assume that the airports operate under variable returns to scale (VRS) rather than under constant returns to scale (CRS) due to the fact that the airports are not flexible in the short-run considering the choice of input levels. Thus, very small or very large airports are treated in an unbiased way when computing DEA efficiency scores.

In the computation, two questions come in with respect to the scale (Ülkü 2014). The first question deals with the level of inefficiency of the airport, which results from not operating on the optimal size. Unless the efficiency scores from CRS-DEA (CCR) and VRS-DEA (BCC) are equal to each other, inefficiencies due to scale would exist and the level of scale efficiency for input-oriented models or output-oriented models can be computed by the ratio of distances attained from CRS-DEA (CCR) and VRS-DEA (BCC), respectively. For the fact that the distances are the technical efficiency scores from CRS-DEA and VRS-DEA models, scale efficiency can be easily attained by the ratio of technical efficiency scores of two specifications (Coelli et al. 2005; Färe, Grosskopt and Lovell 1994).

The second question investigates whether the airports operate under decreasing, constant or increasing returns to scale (DRS, CRS and IRS, respectively). Some literature on production of airport services shows that a vast majority of airports operate under IRS, mainly due to the large, indivisible fixed investments, which cannot be matched with an adequate traffic demand. For instance, Martin and Voltes-Dorta (2011) argues that even for large hubs, there is a potential advantage of expanding the size of operations. A Cobb-Douglas type long-run cost function applied to forty-one (41) airports from Australia, Asia, North America and Europe delivers these conclusions. Furthermore, Assaf (2010) estimates a Cobb-Douglas specification of cost function and the analysis delivers results that support increasing returns to scale production.

Empirical Studies on Airport Efficiency

Parker (1999) analyses the effects of privatization on the efficiency level of British airports using Data Envelopment Analysis. The results show that privatization had no noticeable impact on the technical efficiency of the airport business. Oum, Adler and Yu (2006) from the year 2001-2003, conducted a research on the effect of ownership type to productive efficiency and profitability using panel data for the major airports looking at the airport cost efficiency in the Asia-pacific, Europe and North America, in which Stochastic frontier was used for the analyses. Their results suggest that airports with government majority share ownership structure and those owned by multi-level government are significantly less efficient than the privately majority ownership airports, which means that most of the publicly owned airports need to adjust most of their policy or government should even embrace the public private partnership in other to move most of the airports to increase their productivity and efficiency.

Tenge (2012) asserts that the quality of airport services and the ability to constantly innovate these qualities are important variables that contribute to the overall attractiveness of an airport. In many cases, airport management underestimates the necessity of insight into the needs of clients. Sutia, Sudarma and Rofiaty (2013) have analysed the relationship among human capital, leadership and strategic orientation with company performance, especially the influence of human capital investment on airport performance. In carrying out their research, airports aim at maximizing the movement of aircraft, thus increasing the efficiency of operations in the competitive environment in which they function.

In many countries, airports have turned from state monopolies into competing operators, and flight directions are determined by market changes. In addition, the emergence of low cost carriers in the market forces airports to increase the efficiency of the existing infrastructure in order to preserve competitiveness and to maintain their sales (Pabedinskaite and Akstinaite 2014). Hooper and Hensher (1997) studied the evolution of total factor productivity of Australian airports for the period 1988-1992 using index number methods for the analyses. More so, Pels, NijKamp and Rietveld (2001) also carried out a study on airport productivity and efficiency of European airports; after their analysis with two different models (Data Envelopment Analysis and Stochastic Frontier Analysis), the two results were compared. Their results show that the stochastic frontier model reproduces the DEA results in a quite reasonable way. Furthermore, Barros and Dieke (2008) applied stochastic frontier model in their study of technical efficiency of airports in the United Kingdom. There are so many studies on DEA around the developed world but within African nation, there are individual studies with attempts to link operational performance (Stephens and Ukpere 2011; Oduwole 2014; Nwaogbe et al. 2015; Barros et al. 2015; Wanke et al, 2016; Oyesiku et al. 2016; Pius et al. 2017). This study will consider two output variables (passenger throughput and aircraft movement) and five input variables (terminal capacity, number of employees, total assets, runway dimension and total cost).

Furthermore, performance analysis has become a crucial method for controlling and managing various airport practices and decision making (Wanke, Barros and Nwaogbe 2016). The researchers studied and evaluated production efficiency in Nigerian airports using Fuzzy-DEA model. However, the study of DEA models, can be applied in any transport sector (airports, seaports, road and rail transport) assuming the inputs and outputs of the airports are known with absolute precision (Wanke et al. 2016). In the study, the findings show that when controlling the fuzziness and randomness during the study, capacity cost was found to be the only significant variable, in addition to a learning component represented by trend. More so, an appraisal of airport terminal performance was conducted by Pius, Nwaogbe, Akerele and Masuku (2017) focusing on Murtala Muhammed International Airport in Nigeria. The study concluded that terminal improvement assisted MMIA in coping with the increased numbers of passenger's and aircraft in terms of improving operational performance. They also suggested that to sustain the terminal infrastructure on the long term, the aviation policy makers and the implementers should consider private sector financing strategy (Pius et al. 2017). Furthermore, Nwaogbe et al. (2017) research conducted an assessment of the safety measures and efficiency at the Nnamdi Azikiwe International Airport. Findings from their study confirm that some of the safety measures, if effective, lead to the efficiency in airport operations at the airside and landside. This can guarantee long-term industry advancement and economic benefits will emanate from the sustained investment.

Barros et al. (2017) studied efficiency in Nigerian Airports using Stochastic Frontier Model (Cost Function) that captures the impact of unobserved managerial ability. In the study, they utilized Alvarez, Arias and Greene (2004) AAG model. Their study findings show that contextual variables if allowed will simultaneously control the impacts of managerial ability on efficiency. They also find out that variation inefficiency scores are more sensitive to labour than capital cost but indicate a negative impact of regulation and hub operations on efficiency levels (Barros et al. 2017). Nwaogbe, Ogwude and Ibe (2017) also studied on airport efficiency performance in Nigeria using DEA-BCC model. From the study, the findings show that there is a high significant relationship between the inputs (total assets, runway dimension and employees) and the output produced. The efficiency scores of the airport shows that various airports are operating under constant returns to scale, increasing returns to scale and decreasing returns to scale. Airports operating at the frontier efficiency graph are shown in the production function. Policy implications on how to improve the airports that are inefficient to be efficient were given.

Nwaogbe et al. (2018) also studied the efficiency driver in Nigerian Airports using Bootstrapping DEA-Censored Quartile Regression Approach. Their study combined bootstrapped DEA result with censored quartile regression to assess the impact of contextual variables related to the airports' ownership, location, and network connectivity on different efficiency percentiles. The result showed that the intensity of significant impacts regarding airports' contextual variables may vary between high/low efficiency airports. Policies were derived for the Federal Airport Authority of Nigeria and other stakeholders to use for the enhancement of the operational efficiency level. Wanke, Nwaogbe, and Chen (2017) studied efficiency in Nigerian Ports handling imprecise data with a two-stage fuzzy approach. More precisely, fuzzy data envelopment analysis models for traditional assumptions with respect to scale returns are employed to assess the productivity of Nigerian ports over the course of time. In the second stage, fuzzy regressions based on different rules systems were used to predict the relationship of a set of contextual variables on port efficiency. These contextual variables are related to different aspects of port service level, berth utilization, accessibility, cargo type, and operator type. The results revealed the impact of operator and cargo type on efficiency levels. Policy implications for Nigerian ports were derived.

Method

Data Envelopment Analysis (DEA) Model

Data Envelopment Analysis is commonly used to evaluate the efficiency of a number of producers. A typical statistical approach is characterized as a central tendency approach and it evaluates producers relative to an average producer. In contrast, DEA compares each producer with only the "best" producers. Data Envelopment Analysis provides a clear answer to the airport manager's problem, because it helps in the benchmarking of airports from the results derived from the analysis to meet global standards. DEA is a linear programming based technique. This basic model only requires information on inputs and outputs. DEA incorporates multiple outputs and inputs. In fact, input and outputs can be defined in a very general manner without getting into problems of aggregation. DEA provides scalar measures of relative efficiency by comparing the efficiency achieved by a Decision Making Unit (DMU) with the efficiency obtained by similar DMUs. In the case of a single output this relation corresponds to a production function in which the output is maximal for the indicated inputs. But in the more general case of multiple outputs the relation can be defined as an efficient production possibility, either surfaced or frontier. In running the analysis, DEA solver pro version 13.0 was used.

DEA, occasionally called Frontier Analysis, was introduced by Charnes, Cooper and Rhodes in 1978 (CCR). DEA is a performance measurement technique which can be used for evaluating the relative efficiency of decision-making units (DMUs). The airports now will serve as the DMUs. Efficiency is derived and part of productivity realized where it is a ratio of actual output attained to standard output expected (Sumanth 1984). Mali (1978) expressed together the terms of productivity, effectiveness and efficiency as follows:

$$\text{Productivity index} = \frac{\text{output obtained}}{\text{input expected}} = \frac{\text{Performance achieved}}{\text{reources consumed}} = \text{effectiveness/efficiency} \qquad (1.1)$$

Sumenth (1984) and Ramanathan (2003) expresses efficiency as follows:

$$\text{Efficiency} = \frac{\text{output}}{\text{input}} \quad (1.2)$$

$$\text{Efficiency} = \frac{\text{U weighted sum of outputs of DMU}}{\text{v weighted sum of inputs of DMU}} \quad (1.3)$$

If all weights are assumed to be uniform, this can be expressed mathematically as follows: $\frac{\sum_{r-1}^{n} u_r y_r}{\sum_{r-1}^{n} v_s x_s}$. (1.4)

Where y_r = quantity of output r
u_r = weight attached to output r
x_s = quantity of inputs
v_s = weight attached to inputs

Efficiency of airport can be denoted as = 1: Unit efficiency of an airport is set as $0 < \text{Efficiency} \leq 1$ (Mokhtar and Shah 2013).

That is often inadequate due to the existence of multiple inputs and outputs related to different resources, activities and other factors of production at the airport. The measurement of relative efficiency where there are multiple possibly incommensurate inputs and outputs was addressed by Farrel (1957) and developed by Farrel and Fieldhouse (1962) focusing on the construction of a hypothetical efficient unit as a weighted average of efficiency units to act as a comparator for an inefficient unit. Charnes, Cooper, and Rhodes (1978) models data envelopment analysis of linear programme estimates as the technical efficiency of firms with respect to a production frontier. This study was a further extension of Farrell (1957) idea of estimation of technical efficiency. The CCR-model calculates the relative technical efficiency of Decision Making Units (DMUs) that are similar (for instance airports of the same homogeneous variables) through the analysis with the scale basis of constant returns to scale. They achieved that by building the ratio of a weighted sum of outputs to a weighted sum of inputs. The weight of both inputs and outputs were selected in order to minimize the objective function of the problem with the constraints so that no DMU can have a relative efficiency score greater than one (efficiency < =1). Furthermore, Banker et al. (1984) extended the DEA-CCR model by assuming scale bases as variable returns to scale where performance is bounded by a piecewise linear frontier.

Model Formulation

CCR-model

In formulation of the model, the variable and parameters are used for the study that are needed to carry out. With that, .the model is based on the following variables and parameters:

n = number of airports (DMUs) $\{j = 1, 2, \ldots\ldots, n\}$

y = number of outputs $\{y = 1, 2, \ldots\ldots, R\}$

x = number of inputs $\{x = 1, 2, \ldots\ldots, S\}$

yi = quantity of output r^{th} of output of j^{th} DMU

xi = quantity of input s^{th} of input of j^{th} DMU

ur = weight of r^{th} output

vs = weight of s^{th} input

Looking at the airports (DMUs) and the homogeneous units, Golany and Roll (1989) describes homogeneous unit as an important factor in choosing the DMUs (airports) to be compared and identify the factors that affects the DMUs. Therefore, any DMU with same group of units would behave the same way in terms of objectivity and performance, as far as they are in the same market and observe the same market condition. The factors (inputs and outputs) that enhance the performance evaluation and benchmark are the same. The linear programing model formulation enables the model to compare the relative efficiency of the DMUs (airports). Adopting Charnes et al. (1978) model to solve this production frontier of the 30 airports in Nigeria, we have:

Objective function: $\text{Max}_{\theta\lambda}\ \theta_j$

Subject to:

$$\sum_{i=1}^{n} \lambda_j y_{ri} \geq y_j;\ r = 1, \ldots\ldots, R \quad (1.5)$$

$$\sum_{i=1}^{n} \lambda_i x_{si} \leq \theta_j;\ x_j;\ s = 1, \ldots\ldots, S \quad (1.6)$$

$$\lambda_i \geq 0;\ \forall_i \quad (1.7)$$

Where $y_i = (y_{1i}, y_{2i}, \ldots \ldots, y_{Ri})$ is the output vector, $x_i = (x_{1i}, x_{2i}, \ldots \ldots, x_{Si})$ is the input vector, λ is a 1×1 vector constants. Solving the equation for each one of the n airports of the sample size, n weight and n optimal solution are found in the linear programming problem. Each optimal solution θ_j^* is the efficiency indicator of the airports j and, by construction it satisfies $\theta_j^* \leq 1$. These airports with $\theta_j^* < 1$ are considered inefficient and airports with $\theta_j^* = 1$ are efficient.

Data

The input and output characteristics of the Nigerian airports in 2013 are revealed in table 1.1. The input variables are terminal capacity, runway dimension, number of employees, total assets and total cost, while the output variables are passenger throughputs, and aircraft movements of the 30 airports during the study.

Table 1.1: Characteristics of the Nigerian Airports in 2013

	Inputs					Outputs	
Airports	Terminal capacity (Pax)	Runway dimension (m2)	Employees	Total assets (N)	Total operating cost (N)	Passengers (000s)	Aircraft
ABJ DOM	252	181000	808	29526048386	1121784325	3817142	60515
ABJ INT'L	320	216000	934	78345380972	4354835610	1361303	8011
AKURE	40	126000	72	1970171004	2283221	5525	481
BENIN	250	108000	95	6255839533	370750434	396629	1997
CAL DOM	108	110000	153	617565857	74108206	319757	6950
CALINT'L	100	110250	116	3037237655	45875125	0	0
ENUGU	300	108000	149	10112739813	50971957	0	0
IBADAN	250	108000	87	9920803171	7919526	28436	2915
ILO DOM	202	128000	72	856571757	6574844	47293	3355
ILO INT'L	200	186000	111	10564650736	386639667	0	0
JOS	250	222000	121	158810721	7215496	81758	1870
KAD DOM	285	152000	107	827330558	655727441	210433	6359
KAD INT'L	250	135000	153	448753721	52656553	166765	41
KAN DOM	600	275000	466	254784018	31838308	266653	5722
KAN INT'L	640	315000	532	5262032933	995298550	166765	2068
MKD	63	192000	43	405582707	992027982	2265	382
MAID DOM	200	168000	168	10146690793	521528223	117691	1998
MAID INT'L	50	180000	130	10189660601	59113607l	17751	266
MMA DOM	615	1213435	1252	28331561632	2760775086	4389241	81680
MMA INT'L	3675	234000	1390	27094966746	890652126	3817142	28309
PHC DOM	518	156000	360	9496710128	720248643	1361303	23069
PHC INT'L	700	180000	299	671691131	71068154	14931	909
SOK DOM	194	125000	54	510300399	49062379	70899	2002
SOK INT'L	250	108000	78	2912780597	457945559	46540	139
YOLA DOM	108	120000	124	10223012046	38825983	112820	2243
YOLA INT'L	120	108000	127	7703132065	980735237	12038	70
MINNA	1000	112000	101	448723618	86311953	13322	761
KAT	120	137025	119	859969649	34209952	10813	895
OWERRI	800	121500	131	583606940	68809402	540655	6846
OSUBI	65	81000	20	306796011	33101424	38991	13190

Source: FAAN (2013)

The summary of descriptive statistics for the sample of 30 Nigerian airports used for the DEA-CCR model analysis is shown in table 1.2. The variables descriptive statistics presented are related to major elements of the airport cost structure—(i) labour cost (measured as the total wages/number of employee's ratio); (ii) capacity cost (measured as the total assets/terminal capacity ratio); and (iii) movement cost (measured as the total costs/total landings and take-offs ratio).

Table 1.2: Summary Descriptive Statistics for the Sample

Variables		Min	Max	Mean	SD
Inputs	Terminal Capacity (pax/year)	40.00	3,675	417.50	661.90
	Runway Dimension (m2)	81000	1,213,435	190,540.30	200,792.8
	Number of Employees	20	1,390	279.06	356.46
	Total Assets (current NGN)	158,810,721	7,834,580,972	8,934,796,863	15,555,864,757
	Total Operating Costs (current NGN per year)	2,283,221	4,354,835,610	548,697,248	921,899,169
Outputs	Passenger Throughput (pax per year)	-	4,389,241	581,162	1,214,131
	Aircraft Movements (per year)	-	81,680	8768.1	18,396.59

Analysis of Productivity and Efficiency of Domestic and International Airports in Nigeria

The five evaluation items include the categories of airport ownership and governance, the technical efficiency (i.e. CRS efficiency). The technical efficiency can be obtained from the CCR model. In addition, Coelli et al. (2005) revealed the concept that the assumption in a DEA-CCR model is that all DMUs are operating at an optimal scale. However, imperfect competition, government regulations and constraints on finance, may lead to inability of a firm to operate at an optimal scale.

Result of Analysis for the Thirty Airports using CCR-Model

This section discusses the result of the first basic model of the Data Envelopment Analysis (DEA) CCR-model. The CCR-model calculates the relative technical efficiency of Decision Making Units (DMUs) that are similar (for instance airports of the same homogeneous variables) through the analysis with the scale basis of constant returns to scale.

Correlation Matrix Analysis

The correlation analyses indicate significant positive relationships between the inputs and the outputs, which are isotonic and therefore, justified to be included in the model (Marques and Simoes 2010). The correlation analyses for thirty Nigerian airports show various significant relationships between the inputs and output of the DEA (CCR- model) analysis. Table 1.3 shows the correlation between terminal capacity and passenger throughputs as 0.43519 (44%), meaning that there is weak relationship between the input and the output. This means that the passengers using a terminal are lower than the airport terminal capacity. For terminal capacity and aircraft movement the result shows 0.24355 (24%), which means that there is very weak relationship between the input and the output. Between the runway dimension and passenger throughputs, the analysis shows 0.71907 (72%) in table 1.3, meaning that there is a stronger significant relationship between the input and output; while on the runway dimension and aircraft movement, the result shows 0.67511 (68%). This means that there is a strong significant relationship between the input and output. For the correlation of employees and passenger throughput, the result shows 0.84902 (85%), meaning that there is a stronger significant relationship between the input and the output; while the number of employees and aircraft movement shows 0.67869 (68%) as the result, meaning that there is a strong relationship between the input and output. The result shows 0.82577 (83%) as a significant relationship between passenger and total assets.

Table 1.3: Correlation Matrix of the DEA (CCR-Model)

	Terminal capacity (Pax)	Runway dimension (m2)	Employees	Total assets	Total cost	Passengers	Aircraft
Terminal capacity (Pax)	1	0.14585	0.69684	0.39844915	0.21843521	0.43519	0.24355
Runway dimension (m2)	0.14585	1	0.63106	0.595649062	0.44422	0.71907	0.67511
Employees	0.69684	0.63106	1	0.78262754	0.67339575	0.84902	0.67869
Total assets	0.39845	0.59565	0.78263	1	0.66567486	0.82577	0.72113
Total cost	0.21844	0.44422	0.6734	0.665674865	1	0.5347	0.46985
Passengers	0.43519	0.71907	0.84902	0.825769163	0.53469754	1	0.93932
Aircraft	0.24355	0.67511	0.67869	0.721134172	0.46984758	0.93932	1

The correlation result of total assets and aircraft movement shows 0.72113 (72%) as the result from the correlation analysis which means that there is stronger significant relationship between the input and output. For the total cost and passenger throughputs the correlation analysis result is 0.5347 (53%) which means that there is an average significant relationship between the input and output. The correlation between total cost and aircraft movement in the correlation matrix shows 0.46985 (47%) thus, a weak relationship between the input and the output. Finally, input and output variables have strong and significant relationships in the correlation analysis for runway dimension against passenger throughput, number of employee against passenger throughputs, total assets against passenger throughputs and total assets against aircraft movement; while the input and output with the weakest correlation is terminal capacity against aircraft movement. The study revealed that four input variables have significant correlation to their corresponding output variables.

Analysis of Productivity and Efficiency Scores of Domestic Airports using CCR-Model (CRS)

The productivity and efficiency scores of domestic airports using CCR-Model (CRS) are shown in table 1.4. Among the twenty domestic airports, three airports are operating at a productivity and efficiency score level of 100% which is equal to 1, and these airports are: ABJ DOM, PHC DOM AND OSUBI. While the three least inefficient airports are MINNA, MKD and KAT airports with inefficiency score of 0.0373, 0.0148 and 0.0123 respectively. The DEA model benchmarks airport at efficiency score of > = 1, once the efficiency score is < 1 the airport is termed to be inefficient.

Table 1.4: Domestic Airport Productivity and Efficiency Scores

No.	DMU(AIRPORTS)	Score	Rank
1	ABJ DOM	1	1
2	PHC DOM	1	1
3	OSUBI	1	1
4	JOS	0.9635	4
5	MMA DOM	0.8973	5
6	KAN DOM	0.8497	6
7	ENUGU	0.8321	7
8	CAL DOM	0.5157	8
9	KAD DOM	0.4696	9
10	SOK DOM	0.3361	10
11	YOLA DOM	0.2769	11
12	BENIN	0.2505	12
13	ILO DOM	0.2496	13
14	AKURE	0.1879	14
15	MAID DOM	0.1596	15
16	OWERRI	0.1475	16
17	IBADAN	0.1295	17
18	MINNA	0.0373	18
19	MKD	0.0148	19
20	KAT	0.0123	20

Analysis of Productivity and Efficiency Scores of International airports using CCR-Model (CRS)

The international airports on the other hand, were operating below 100% which is < 1. We can conclude that the international airports in Nigeria during the study period were operating at an inefficiency level, since the productivity and efficiency scores of the airports are < 1 (less than 100%) as shown in table 1.5.

Table 1.5: International Airport Productivity and Efficiency Scores

No.	DMU(AIRPORTS)	Score	Rank
1	MMA INT'L	0.9463	1
2	KAD INT'L	0.7621	2
3	MAID INT'L	0.5735	3
4	PHC INT'L	0.2294	4
5	SOK INT'L	0.2256	5
6	KAN INT'L	0.1953	6
7	ABJ INT'L	0.1462	7
8	YOLA INT'L	0.1304	8
9	ILO INT'L	0.1153	9
10	CAL INT'L	0.015	10

Analysis of Productivity and Efficiency Scores of Domestic and International Airports combined using CCR-Model (CRS)

An estimation of the efficiency scores using the CCR-model is shown in table 1.6. In analysing the operating efficiency of the airports, we need to look at various evaluation categories of the DMUs ownership and governance like the technical efficiency (i.e. CRS efficiency), the pure technical efficiency (i.e. VRS efficiency), the scale efficiency and the returns to scale. Using DEA model to analyse the productivity and efficiency of Nigeria airports, the technical efficiency can be obtained from the CCR model while the BCC model can be used to obtain the pure technical efficiency. According to Lai (2013), technical efficiency is divided by pure technical efficiency to obtain the scale efficiency. The derived efficiency values are then used to analyse the operating efficiency of each airport. Furthermore, Coelli et al. (2005) assumption in a DEA-CCR model is that, all DMUs are operating at an optimal scale. In practice this is hard to achieve, since imperfect competition, government regulations, constraints on finance and lack of adequate infrastructure may cause the airports not to operate at an optimal scale, thereby making it difficult for the operators to meet organizational and government objectives of setting-up the airports.

Table 1.6: Productivity and Efficiency Scores of CCR-Models (CRS) for 30 Major Airports in Nigeria (both Domestic and International Combined)

No.	DMU(AIRPORTS)	Score	Rank
1	ABJ DOM	1	1
2	ABJ INTL	0.1462	23
3	AKURE	0.1879	20
4	BENIN	0.2505	15
5	CAL DOM	0.5157	11
6	CAL INT'L	0.015	28
7	ENUGU	0.8321	8
8	IBADAN	0.1295	25
9	ILO DOM	0.2496	16
10	ILO INT'L	0.1153	26
11	JOS	0.9635	4
12	KAD DOM	0.4696	12
13	KAD INT'L	0.7621	9
14	KAN DOM	0.8497	7
15	KAN INT'L	0.1953	19
16	MKD	0.0148	29
17	MAID DOM	0.1596	21
18	MAID INT'L	0.5735	10
19	MMA DOM	0.8973	6
20	MMA INT'L	0.9463	5
21	PHC DOM	1	1
22	PHC INT'L	0.2294	17
23	SOK DOM	0.3361	13
24	SOK INT'L	0.2256	18
25	YOLA DOM	0.2769	14
26	YOLA INT'L	0.1304	24
27	MINNA	0.0373	27
28	KAT	0.0123	30
29	OWERRI	0.1475	22
30	OSUBI	1	1
	Average	0.4223	
	Max	1	
	Min	0.0123	
	St Dev	0.3571	

From the analysis, the results of the CCR model show efficiency. Scores for the thirty airports in Nigeria are shown in table 1.6. The efficiency indices inclined from 0.0123 to 1 for CCR-model result. The result shows that at least three (3) different airports are considered to be technically efficient from the CCR-model analysis result. Furthermore, when analysing the CCR-model, it was observed that the model is interested in constant returns to scale and its efficiency score (1) result shows that three (DMUs) airports are efficient. The DMUs (airports) are: Nnamdi Azikiwe Airport (ABJ DOM); Port Harcourt Airport (PHC DOM) and Warri Airport (OSUBI); they are efficient airports in Nigeria from the CCR-model result. Among the efficient airports are the Nnamdi Azikiwe

Airport (ABJ DOM), Port Harcourt Airport (PHC DOM) and Warri Airport (OSUBI). ABJ DOM and PHC DOM are owned by the Federal government and also operated by the Federal Airports Authority of Nigeria (public), while Warri Airport (OSUBI) is owned by the private sector and it is also operated likewise (Shell Petroleum Development Company). These efficient airports have a max-efficiency value of 1.0.

The airports that are inefficient are as follows: Nnamdi Azikiwe International Airport, Abuja (ABJ INT'L); Akure Airport (AKURE); Benin Airport (BENIN); Margaret Ekpo Airport, Calabar (CAL DOM); Margaret Ekpo International Airport, Calabar (CAL INT'L); Akanu Ibiam Airport, Enugu (ENUGU); Ibadan Airport (IBADAN); Ilorin Airport (ILO DOM); Ilorin International Airport (ILO INT'L); Yakubu Gowon Airport, Jos (JOS); Kaduna Airport (KAD DOM); Kaduna International Airport (KAD INT'L); Mallam Aminu Kano Airport (KAN DOM); Mallam Aminu Kano International Airport (KAN INT'L); Markurdi Airport (MKD); Maiduguri Airport (MAID DOM); Maiduguri International Airport (MAID INT'L); Murtala Muhammed Airport, Lagos (MMA DOM); Murtala Muhammed Airport (MMA INT'L); Port Harcourt International Airport (PHC INT'L); Sadiq Abubakar III Airport, Sokoto (SOK DOM); Sadiq Abubakar III International Airport, Sokoto (SOK INT'L); Yola Airport (YOLA DOM); Yola International Airport (YOLA INT'L); Minna Airport (MINNA); Katsina Airport (KAT) and Sam Mbakwe Airport, Owerri (OWERRI). The least in technical efficiency airport from the CCR-model is KAT. Sengupta (1995) states that industrial competitiveness can be evaluated through average efficiency analysis. The average efficiency for the 30 DMUs of the CCR-model is 0.4223 (42%). This means that a relationship exists between the input and output values depending on the importance or size of the data set. Although some of the airports efficiency, values are above the model average efficiency scores, the model result shows that the least technically efficient DMU is Katsina Airport (KAT).

The issue of this inefficiency may be that some airports were targeted for less air carrier, and also due to low infrastructure in the airports, and may as well be due to low standard of aircraft maintenance by the airline which leads to many aircraft accidents at the airports. Also that might cause some airlines to shift their operations to the neighbouring airports or neighbouring country's airports. Example is the DANA airline crash in year 2013 and other aircraft crashes in the country involving a total of 2,012 passenger's/crew members. This happened between 1969-2012 (*www.thenigerianvoice.com*).

Furthermore, a number of points emerge from the basic DEA models as follows:

- Three airports are on the efficient frontier; there is need to help Federal Airports Authorities of Nigeria through suggestions and recommendations to improve the operations and the management techniques of the airports that are not efficient.
- Using the best practice of efficiency evaluation in the study, it was observed that almost all Nigerian airports are operated at a high level of relative inefficiency, with the exception of 3 airports from the CCR-model that are efficient.
- Going through the efficiency model CCR-model (CRS) of the Data Envelopment Analysis, all efficient airports are determined by the CCR model.
- Also according to the CCR scores, there are only 27 airports that are operated relatively inefficiently.
- Among these inefficient airports in CCR model, **KAT (Katsina Airport)** score is relatively lower than other airports results (0.0123 in CRS efficiency).

More so, economic and financial crises are facing most air carriers in Nigeria. Those have caused the airlines to face high airport charges problem thereby leading them to run away from most of such airports. Another case is the issue of insecurity such as Boko Haram (Terrorism), which affected some of the airports in the North-East, North-West and kidnapping in the Niger Delta region of the country. The airports that might be affected are Kaduna Airport (KAD DOM); Kaduna International Airport (KAD INT'L); Mallam Aminu Kano Airport (KAN DOM); Mallam Aminu Kano International Airport (KAN INT'L); Maiduguri Airport (MAID DOM); Sadiq Abubakar III Airport, Sokoto (SOK DOM); Sadiq Abubakar III International Airport, Sokoto (SOK INT'L); Yola Airport (YOLA DOM); Yola International Airport (YOLA INT'L); Minna Airport (MINNA); Katsina Airport (KAT); Port Harcourt International Airport (PHC INT'L); Margaret Ekpo Airport, Calabar (CAL DOM) and Margaret Ekpo International Airport (CAL INT'L) (see table 1.1 for names of airports and locations). This might be part of the factors that caused the low productivity and efficiency of some airports.

Generally, going through the overall efficiency performance for all the airports, it was observed that the largest percentage of respondents that performed most efficiently is 10% while 90% of the observations are inefficient in the CCR-model analysis. A slight increase in both percentages of efficient airports and average efficiency scores means that airport operations are becoming more competitive. Sarkis (2000) postulated in his study that with less than half of the airports in their sample size, still not all the airports obtained efficiency scores equal to 1, rather, there is an ample room to increase efficiency when compared with those of the other airports.

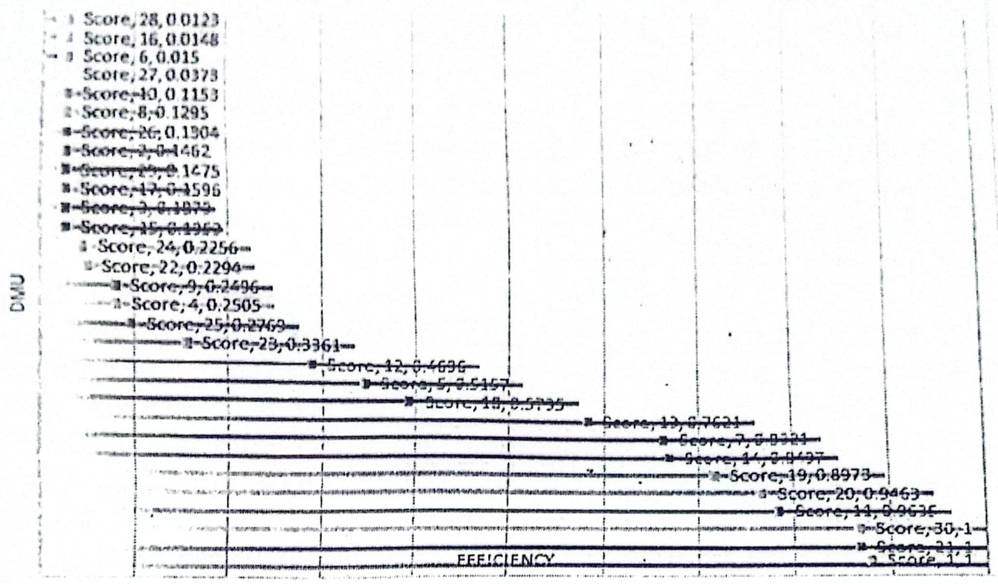
Estimation of Production Function

Estimation of Production Function using CCR-DEA Model (CRS) for Domestic and International Airports in Nigeria

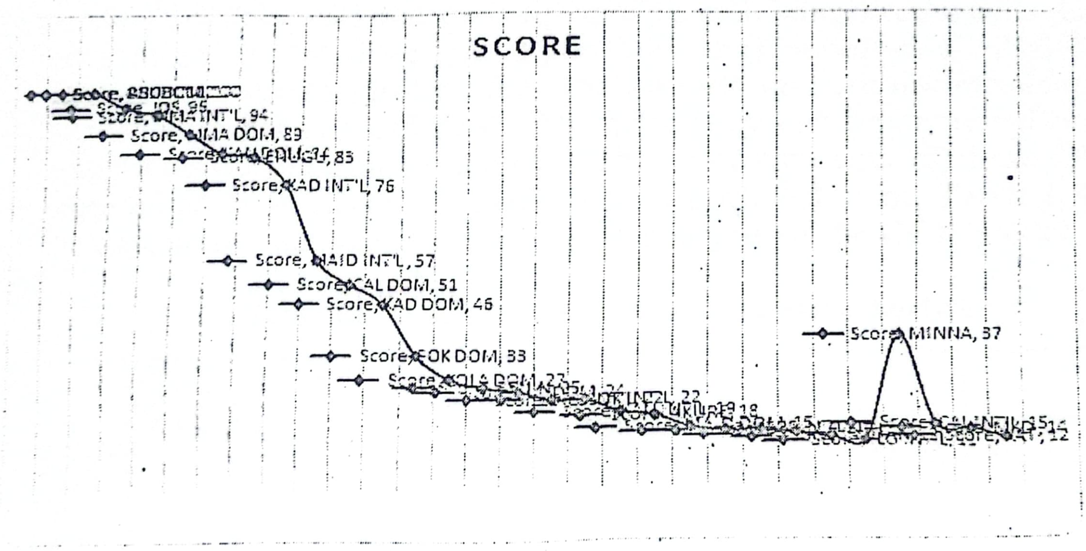
The production function efficiency scores from the DEA-CCR model is shown in table 1.8. The result of the DEA-CCR shows the constant returns to scale of the airports. That is, airports that are operating based on the same level of inputs to give same level of outputs. The ranking position is based on the efficiency scores from the DEA (CCR-Model) analysis in table 1.7. It shows that Nnamdi Azikiwe Airport, Abuja (ABJ DOM); Port Harcourt Airport (PHC DOM) and Warri Airport (OSUBI) are ranked the first or best airports from the CCR-model result. Among the three efficient airports, Warri Airport (OSUBI) is privately managed by the Shell Petroleum Development Company Limited. The remaining two airports are public owned airports. The remaining DMUs (airports) are also displayed in the fourth column of both models on table 1.7.

Table 1.7: CCR-Model DEA Model Efficiency Ranking for Major Nigeria Airports

No.	DMU	Score	Rank
1	ABJ DOM	1	1
21	PHC DOM	1	1
30	OSUBI	1	1
11	JOS	0.9635	4
20	MMA INT'L	0.9463	5
19	MMA DOM	0.8973	6
14	KAN DOM	0.8497	7
7	ENUGU	0.8321	8
13	KAD INT'L	0.7621	9
18	MAID INT'L	0.5735	10
5	CAL DOM	0.5157	11
12	KAD DOM	0.4696	12
23	SOK DOM	0.3361	13
25	YOLA DOM	0.2769	14
4	BENIN	0.2505	15
9	ILO DOM	0.2496	16
22	PHC INT'L	0.2294	17
24	SOK INT'L	0.2256	18
15	KAN INT'L	0.1953	19
3	AKURE	0.1879	20
17	MAID DOM	0.1596	21
29	OWERRI	0.1475	22
2	ABJ INT'L	0.1462	23
26	YOLA INT'L	0.1304	24
8	IBADAN	0.1295	25
10	ILO INT'L	0.1153	26
27	MINNA	0.0373	27
6	CAL INT'L	0.015	28
16	MKD	0.0148	29
28	KAT	0.0123	30



(a)



(b)

Fig. 1.1: Production function graph from CCR-model of DEA.

Figure 1.1(a&b) shows the production function efficiency scores result. It shows the airport production frontier graph. The airports on the frontier graph are ABJ DOM, PHC DOM and OȘUBI. The result is from the CCR-model which considered constant returns to scale of input and output variables. These three airports ABJ DOM, PHC DOM and OSUBI on the frontier means that they are operating at efficiency level. While the inefficient airports are below the frontier. The least efficient airport among the thirty sampled airports is Katsina (KAT) airport with efficiency score of 0.0123. Furthermore, the other DMUs (airports) as shown in figure 1.1, express accordingly the efficiency ranking order from the analysis of the CCR-model result.

Slack Variable Analysis

The slack is the additional improvement (increase in outputs and/or decrease in inputs) that needs to be made for a unit to become efficient. A slack variable analysis can provide guidance for the researcher to observe if there is any improper resource allocation and find a way of utilizing the inputs and outputs in the DMU. Hence, a relatively inefficient DMU can help to determine how to adjust inputs in order to increase outputs. Analysis of the different variables are separated into the CCR model and the BCC model. The CCR model (i.e. the slack variable analysis of CRS efficiency) represents the long-term direction of the DMUs while the BCC model (the slack variable analysis of VRS efficiency) represents the short-term improvement direction of the DMUs (Cooper et al. 2006). Slack analysis provides control on how the airports that are not efficient can be improved to become efficient. This efficiency can be achieved but could sometimes be difficult to achieve. The improvements of these DMUs is required so as to make the inefficient airports efficient. Table 1.8 shows the descriptive statistics from the slack analysis of the CCR-model.

Table 1.8: Descriptive Statistics of the Slack Analysis

	Score	Rank	Terminal capacity (Pax)	Runway dimension (m2)	Employees	Total assets	Total cost	Passengers	Aircraft
Average	0.4223	15.4	253.6071	58448.2503	116.617	1.681E+09	92843226	5102.74	9885.46
Max	1	30	2920.84	659134.091	773.921	1.358E+10	1.47E+09	79758.4	35717.2
Min	0.0123	1	0	0	0	0	0	0	0
St Dev	0.3571	8.962	552.0385	127965.2535	163.321	2.843E+09	2.84E+08	15894.4	10286.7

The table shows various slack variable inputs and outputs used in the projection with the average efficiency scores of 0.4223, maximum efficiency score of 1, minimal efficiency score of 0.0123 and a standard deviation of 0.3571. This indicates that the data used are authentic.

Tables 1.9 and 1.10 show the results of the long-term projection of the individual airports in Nigeria. From the analysis of the CRS-model efficiency of different variables, 27 of the 30 airports were observed to be inefficient. Going through the input variables, it was recommended that the 27 airports, over the CRS-model (long-term projection), can reach an efficiency level, by reducing the inputs for all inefficient airports in order to become relatively efficient.

Table 1.9: Long-term Projection of the Nigerian Airports Inputs

DMU	Score	Rank	Terminal capacity (Pax)			Runway dimension (m2)			Employees			Total assets			Total cost		
			Data	Projection	Diff.(%)	Data	Projection	Diff.(%)	Data	Projection	Diff.(%)	Data	Projection	Diff.(%)	Data	Projection	Diff.(%)
ABJ INTL	0.15	23	320	320	0	216000	216000	0	528	515.1	-2.443	1.20E+10	1.20E+10	0	2.20E+09	6.90E+08	-68.46
AKURE	0.19	20	40	7.298	-81.76	126000	9093.95	-92.78	58	0.0079	-99.99	1.10E+09	1.80E+07	-98.36	1760000	1760000	0
BENIN	0.25	15	250	95.88	-61.65	108000	108000	0	87	4.6452	-94.66	4.50E+09	3.50E+08	-92.25	2.90E+07	2.90E+07	0
CAL DOM	0.52	11	180	110.4	-38.66	110000	110000	0	90	11.029	-87.75	5.40E+08	5.40E+08	0	5.10E+07	4.00E+07	-21.73
CAL INTL	0.02	28	160	160	0	110250	110250	0	103	48.314	-53.09	1.50E+09	1.50E+09	0	1.60E+08	9.50E+07	-41.48
ENUGU	0.83	8	300	101.2	-66.28	108000	108000	0	127	7.2531	-94.29	2.00E+09	4.30E+08	-79.03	3.30E+07	3.30E+07	0
IBADAN	0.13	25	200	25.95	-87.03	108000	32337.8	-70.06	71	0.028	-99.96	4.00E+09	6.40E+07	-98.41	6258500	6258500	0
ILO DOM	0.25	16	170	17.48	-89.72	128000	21779	-82.99	60	0.0183	-99.97	6.80E+08	4.30E+07	-93.65	4215000	4215000	0
ILO INTL	0.12	26	200	197.8	-1.107	136000	136000	0	93	24.134	-74.05	1.10E+09	1.10E+09	0	2.30E+08	7.60E+07	-67.12
JOS	0.96	4	250	21.18	-91.53	222000	26388	-88.11	189	0.0228	-99.98	1.10E+08	5.20E+07	-53.91	5107000	5107000	0
KAD DOM	0.47	12	200	130.3	-34.86	152000	152000	0	90	4.2351	-95.29	4.20E+08	4.20E+08	0	5.90E+07	3.60E+07	-38.83
KAD INTL	0.76	9	250	78.69	-68.77	135000	97307.9	-27.92	133	0.0841	-99.94	1.90E+08	1.90E+08	0	3.00E+07	1.90E+07	-38.06
KAN DOM	0.85	7	520	75.76	-85.52	275000	91918.7	-66.58	400	2.0794	-99.98	1.40E+09	1.80E+08	-87.12	1.80E+07	1.80E+07	0
KAN INTL	0.2	19	640	344.5	-46.15	315000	315000	0	486	45.641	-90.61	2.00E+09	2.00E+09	0	6.70E+08	1.40E+08	-79.52
MKD	0.01	29	65	65	0	192000	76958	-59.92	32	6.0923	-80.96	2.80E+08	2.80E+08	0	6.70E+07	2.20E+07	-66.79
MAID DOM	0.16	21	200	200	0	168000	168000	0	100	100	0	7.20E+09	2.70E+09	-62.87	2.40E+08	1.70E+08	-29.78
MAID INTL	0.57	10	50	50	0	180000	37229.8	-79.32	101	97.542	-3.423	5.70E+09	2.20E+09	-62.64	1.30E+08	1.30E+08	0
MMA DOM	0.9	6	615	615	0	1213435	554301	-54.32	1010	825.12	-18.31	2.30E+10	1.90E+10	-16.81	1.10E+09	1.10E+09	0
MMA INTL	0.95	5	3675	754.2	-79.48	234000	234000	0	1195	421.08	-64.76	1.70E+10	1.20E+10	-30.36	6.80E+08	6.80E+08	0
PHC INTL	0.23	17	700	155.1	-77.7	180000	180000	0	268	5.9027	-97.8	5.30E+08	5.30E+08	0	7.30E+07	4.40E+07	-39.44
SOK DOM	0.34	13	520	58.55	-81.71	125000	72938.4	-41.65	40	0.063	-99.84	1.40E+08	1.40E+08	0	1.70E+07	1.40E+07	-18.92
SOK INTL	0.25	18	250	87.59	-64.96	108000	108000	0	65	0.5518	-99.15	1.40E+10	2.20E+08	-98.36	2.20E+07	2.20E+07	0
YOLA DOM	0.13	24	150	97.24	-35.16	120000	120000	0	102	0.5679	-99.44	3.00E+09	2.50E+08	-91.78	2.40E+07	2.40E+07	0
YOLA INTL	0.13	24	120	120	0	108000	108000	0	80	80	0	5.70E+09	2.00E+09	-65.12	4.40E+08	1.20E+08	-73.43
MINNA	0.04	27	1000	71.33	-92.81	112000	89631.8	-19.97	59	[illegible]	-99.91	1.80E+08	1.80E+08	0	6.20E+07	1.70E+07	-72.08
KAT	0.01	30	120	72.33	-39.73	157000	99128.3	-34.23	67	0.0779	-99.88	7.00E+08	1.80E+08	-74.74	1.70E+07	1.70E+07	0
OWERRI	0.15	22	600	105.1	-56.07	121500	121500	0	116	3.8363	-96.59	4.40E+08	3.50E+08	-20.4	3.00E+07	3.00E+07	0
AVERAGE	0.15	22.5	500	212.53	-43.434	168750	168750	0	322	259.468	-49.57	6.03E+09	5.99E+09	-10.2	1.09E+09	3.54E+08	-34.23

Table 1.10: Long-term Projection of the Nigerian Airports Outputs

DMU	Score	Rank	Passengers			Aircraft		
			Data	Projection	Diff.(%)	Data	Projection	Diff.(%)
ABJ INT'L	0.146	23	2.00E+05	1250918	583.8	3364	36436	983.12
AKURE	0.188	20	1243	15948.886	1183	238	1266.4	432.11
BENIN	0.251	15	46377	200899.33	333.2	3825	15269	299.2
CAL DOM	0.516	11	1.00E+05	220517.97	93.9	2740	15870	479.18
CAL INT'L	0.015	28	4534	302618.92	6574	122	17213	14009
ENUGU	0.832	8	2.00E+05	207482.43	20.18	5152	15401	198.93
IBADAN	0.13	25	2780	56713.695	1940	583	4503.3	672.44
ILO DOM	0.25	16	6292	38195.77	507.1	757	3032.9	300.65
ILO INT'L	0.115	26	44589	386719.2	767.3	757	27110	3481.3
JOS	0.964	4	44589	46278.955	3.79	1101	3674.8	233.77
KAD DOM	0.47	12	1.00E+05	276937.38	112.9	1699	21374	1158.1
KAD INT'L	0.762	9	1.00E+05	170657.58	31.22	757	13551	1690.1
KAN DOM	0.85	7	1.00E+05	161206.08	17.69	3496	12801	266.15
KAN INT'L	0.195	19	1.00E+05	666966.23	412.1	2038	46153	2164.6
MKD	0.015	29	2144	144948.17	6661	147	10781	7234.1
MAIDDOM	0.16	21	76799	481303.98	526.7	1241	25432	1949.3
MAID INT'L	0.574	10	1.00E+05	226791.86	74.38	757	6220.9	721.78
MMA DOM	0.897	6	2.00E+06	2337922.1	11.44	46733	85956	83.929
MMA INT'L	0.946	5	1.00E+06	1336423.6	5.679	15709	47550	202.69
PHC INT'L	0.229	17	75741	330189.3	335.9	1639	25356	1447.1
SOK DOM	0.336	13	42999	127918.62	197.5	890	10157	1041.3
SOK INT'L	0.226	18	42999	190566.52	343.2	757	15063	1889.8
YOLA DOM	0.277	14	58604	211626.45	261.1	1397	16735	1097.9
YOLA INT'L	0.13	24	42999	329794.59	667	7.57	16258	2047.6
MINNA	0.037	27	2891	157195.43	533.7	466	12482	2578.6
KAT	0.012	30	1978	161209.6	8050	154	12551	8050.1
OWERRI	0.148	22	32826	222504.22	577.8	1248	17108	1270.8
AVERAGE	0.1469	22.5	107877	736711.09	580.8	2306	26772.1	1126.98

The total percentage reduction of the airports long-term projection differences for terminal capacity are as follows: Akure Airport by about 82%; Benin Airport 62%; Margaret Ekpo Airport, Calabar 39%; Akanu Ibiam International Airport, Enugu 66%; Ibadan Airport 87%; Ilorin Domestic Airport 90%; Ilorin International Airport 1%; Yakubu Gowon Airport, Jos 92%; Kaduna Airport 35%; Kaduna International Airport 69%; Mallam Aminu Kano Airport 86%; Mallam Aminu Kano International Airport 46%; Murtala Muhammed International Airport 79%; Port Harcourt International Airport 78%; Sadiq Abubakar III

Airport, Sokoto 82%; Sadiq Abubakar III International Airport, Sokoto 65%; Yola Airport 35%; Minna Airport 93%; Katsina Airport 40% and Sam Mbakwe Airport, Owerri 87%. On the average, the Federal Airport Authority of Nigeria should advise the airport management to reduce its terminal capacity input of the airports that are inefficient by 43% so as to enable them increase their efficiency level.

With regard to runway dimension, Akure Airport should reduce their input by 93%, Yakubu Gowon Airport, Jos 88%, Kaduna International Airport 28%, Mallam Aminu Kano Airport 67%, Makurdi Airport 60%, Maiduguri International Airport 79%, Murtala Muhammed Airport 54%, Sadiq Abubakar III Airport, Sokoto 42%, Minna Airport 20% and Katsina Airport 34%. But on the average, nothing should be reduced.

With regard to the number of employees, the inputs should be reduced as follows: Nnamdi Azikiwe International Airport, Abuja 2%; Akure Airport 99.9%; Benin Airport 95%; Margaret Ekpo Airport, Calabar 88%; Margaret Ekpo International Airport, Calabar 53%; Akanu Ibiam Airport, Enugu 94%; Ibadan Airport 99.9%; Ilorin Domestic Airport, Ilorin 99.9%; Ilorin International Airport 74%; Yakubu Gowon Airport, Jos 99.9%; Kaduna Airport 95%; Kaduna International Airport 99.9%; Mallam Aminu Kano Airport, Kano 99.9%; Mallam Aminu Kano International Airport 91%; Makurdi Airport 81%; Maiduguri International Airport 3%; Murtala Muhammed Airport, Lagos 18%; Murtala Muhammed International Airport, Lagos 65%; Port Harcourt International Airport 98%; Sadiq Abubakar III Airport, Sokoto 99.8%; Sadiq Abubakar III International Airport 99%; Yola Airport 99%; Minna Airport 99.9%; Katsina Airport 99.8%; and Sam Mbakwe Airport, Owerri 97%; while on the average for all the airports, inputs should be reduced by 50% so as to achieve efficiency for inefficient airports.

With regard to the total assets, inputs of all the airports should be reduced as follows: Akure Airport 98%; Benin Airport 92%; Akanu Ibiam Airport, Enugu 79%; Ibadan Airport 98%; Ilorin Domestic Airport 94%; Yakubu Gowon Airport, Jos 54%; Mallam Aminu Kano Airport, Kano 87%; Maiduguri Airport 63%; Maiduguri International Airport 62%; Murtala Muhammed Airport 17%; Murtala Muhammed International Airport 31%; Sadiq Abubakar III International Airport 98%; Yola Airport 92%; Yola International Airport 65%; Katsina Airport 75% and Sam Mbakwe Airport, Owerri 20%. On the average, the Federal Airport Authority should reduce the inputs by 10% to increase efficiency of the airports. Furthermore, with regard to total cost of the airports, the inputs should be reduced as follows: Nnamdi Azikiwe International Airport 68%, Margaret Ekpo Airport 22%, Margaret Ekpo International Airport 41%, Ilorin International Airport 67%, Kaduna Airport 39%, Kaduna International Airport 38%, Mallam Aminu Kano International Airport

80%, Makurdi Airport 67%, Maiduguri Airport 30%, Port Harcourt International Airport 39%, Sadiq Abubakar III Airport 19%, Yola International Airport 72% and Minna Airport 72%. On the average, the Federal Airport Authority of Nigeria should reduce the inputs by 34% in order to minimize the inefficiency of airports.

Among the output variables, it was recommended that the 27 airports over the CRS (long-term projection) should reach an efficient output by increasing the outputs for all inefficient airports in order to become relatively efficient. The total percentage of the airports long-term projection differences for passenger throughputs are as follows: Nnamdi Azikiwe International Airport, Abuja 584%; Akure Airport 1183%; Benin Airport 333%; Margaret Ekpo Airport, Calabar 94%; Margaret Ekpo International Airport, Calabar 6574%; Akanu Ibiam Airport Enugu 20%; Ibadan 1940%; Ilorin Domestic Airport 507%; Ilorin International Airport 767%; Yakubu Gowon Airport, Jos 4%; Kaduna Airport 113%; Kaduna International Airport 31%; Mallam Aminu Kano Airport 18%; Mallam Aminu Kano International Airport 412%; Makurdi Airport 6661%; Maiduguri Airport 527%; Maiduguri International Airport 74%; Murtala Muhammed Domestic Airport, 11%; Murtala Muhammed International Airport 6%; Port Harcourt International 336%; Sadiq Abubakar III Airport 1987%; Sadiq Abubakar III International 343%; Yola Airport 261%; Yola International Airport 667%; Minna Airport 5337%; Katsina Airport 8050% and Sam Mbakwe Airport, Owerri 578%. But on the average, the airports need to increase their passenger throughput by 581% for them to reach their maximum output. This will make the airports to become efficient.

Furthermore, for aircraft movement, the airports are advised to increase as follows: Nnamdi Azikiwe International Airport, Abuja 983%; Akure Airport 479%; Benin Airport 299%; Margaret Ekpo Airport, Calabar 479%; Margaret Ekpo International Airport 14009%; Akanu Ibiam Airport, Enugu 199%; Ibadan Airport 672%; Ilorin Airport 304%; Ilorin International Airport 3481%; Yakubu Gowon Airport, Jos 234%; Kaduna Airport 1158%; Kaduna International Airport 1690%; Mallam Aminu Kano Airport 266%; Mallam Aminu Kano International Airport 2165%; Makurdi Airport 7234%; Maiduguri Airport. 1949%; Maiduguri International Airport 722%; Murtala Muhammed Domestic Airport, Lagos 84%; Murtala Muhammed International Airport, Lagos 203%; Port Harcourt International Airport, 1447%; Sadiq Abubakar III Airport 1041%; Sadiq Abubakar III International 1890%; Yola Airport 1098%; Yola International Airport 2048%; Minna Airport 2579%; Katsina Airport 8050% and Sam Mbakwe Airport, Owerri 1271%. As regards the average, the aircraft movement needs to be increased by 1127% so as to make all the airports become efficient.

Finally, amongst all the airports that are inefficient whose inputs need to be reduced and the output increased; the least that needs urgent attention is Katsina Airport. Due to the very low efficiency of the airport, Katsina Airport needs to be closed down for lack of much economic activity. It is apt to note that the operations and proximity of Mallam Aminu Kano Airport is affecting the viability of Katsina Airport. The Katsina Airport can be privatized for possible improvement on the present performance.

From table 1.11 and Appendix E1, the overall CCR-model projection highlights its overall descriptive statistics of efficiency scores, ranks, inputs and outputs of the Nigerian airports. From the analysis, the average efficiency score is 0.4223, maximium efficiency score of 1, minimium efficiency score of 0.0123, while the standard deviation of the efficiency score is 0.3571. This means that on the average during the study, the 30 airports observed show that there is no airport that operates at a maximium efficiency level (operating at an optimal scale of relative efficiency) since the average efficiency score of $0.4223 < 1$.

Table 1.11: Descriptive Statistics of Overall CCR-model Projection of Nigerian Airports

			Terminal capacity (Pax)			Runway dimension (m2)			Employees			Total assets			Total cost			Passengers			Aircraft		
	Score	Rank	Data	Projection	Diff (%)	Data	Projection	Diff (%)	Data	Projection	Diff (%)	Data	Projection	Diff (%)	Data	Projection	Diff (%)	Data	Projection	Diff (%)	Data	Projection	Diff (%)
Average	0.4223	15	471.9	162.326	-43.725	183540	132092	-23.928	222	105.386	-68.406	4.40E+09	2.70E+09	-37.523	2.60E+08	1.60E+08	-21.921	252029	425507	1137.66	5843	20402.1	1566.12
Max	1	30	3075	754.16	0	1213435	554001	0	1195	825.124	0	2.30E+10	1.90E+10	0	2.20E+09	1.10E+09	0	2237563	2137922	[illegible]	46730	85855.6	14028.3
Min	0.0123	1	40	7.2976	-92.827	81000	3030.95	-97.755	0.37	0.0079	-99.986	1.10E+08	1.80E+07	-98.406	1760000	1760000	-79.523	1243	15948.2	0	122	1266.42	0
St Dev	0.3571	9	659.2	182.739	37.454	220793	104303	33.334	293	221.911	41.6809	6.00E+09	5.10E+09	40.303	4.60E+08	2.90E+08	28.8165	535972	530405	2248.51	11403	17032.8	2976.22

With regard to inputs, the descriptive statistics of the CCR-model projection shows the average of the overall projection and differences (%) as follows: 162 (pax) and 44% for terminal capacity, 132092 (m^2) and 24% for runway dimension, 105 persons and 68% for number of employees, 2699204895 and 38% for total assets, 163817719 and 22% for total cost of the airports observed during the study period. The standard deviations are as follows; 183 (pax) and 37% for terminal capacity, 104303 (m^2) and 33% for runway dimension, 222 and 42% for number of employees, 5052856582 and 41% for total assets, and 293151162 and 29% for total cost of the airports observed during the study period.

Finally, the outputs (passenger throughput and aircraft movement) of the descriptive statistics of the projection from the CCR-model show the average projection and differences as follows; 425507 passenger and

1188% for passenger throughput, and 20402 aircraft and 1866% for aircraft movement of the 30 airports during the study period; while the standard deviation of the projection and differences shows that 530405 passengers are projected with 2249% differences for passenger throughput and 17038 aircrafts and 2976% for aircraft movement. These outputs need to be raised based on the values from descriptive statistics so as to reach the optimal scale of productivity and efficiency of the 30 airports that were observed during the study period.

Table 1.12 presents TE scores, PTE scores and SE scores of 30 Nigerian Airports (30 DMUs) alongside the magnitude of technical inefficiency (TIE). The result displayed various descriptive statistics of the stated efficiency scores such as Technical Efficiency, Pure Technical efficiency and Scale Efficiency of Nigerian airports for the study. It also shows the first quartile, third quartile and the intervals during the computation.

Table 1.12: Summary of Findings on Technical Efficiency of Nigerian Airports

STATISTICS	TE (CCR) score	TIE (%)	EFFICIENCY AIRPORTS FOR TE	INEFFICIENCY AIRPORTS TE
NUMBER OF AIRPORTS	30	30	3	27
AVERAGE	0.4223	57.77	1	0.3581
SD	0.3541	35.409	0	0.3154
MIN	0.0123	0	1	0.0123
Q1	0.1465	18.54	1	0.1383
MEDIAN	0.2501	74.995	1	0.2294
Q3	0.8146	85.3475	1	0.5446
MAX	1	98.77	1	0.9635
INTERVAL	(0.068; 0.776)	(22.36;93.18)	(1.00;1.00)	(0.043;0.674)

Conclusion and Policy Implication

This study assesses Nigerian airports productivity, using Data Envelopment Analysis (DEA) model to determine the relative efficiency and productivity among the airports that exist in Nigeria. The model used helped to estimate the efficiency improvement that can be of help in enhancing the airports Decision Making Units (DMUs) that are inefficient to produce more outputs for the airports to contribute to the economic development of the country and foreign direct investments. In the analysis, the input data used includes terminal capacity, runway dimension, number of employees, total assets and total cost, while the output data used include passenger throughput and aircraft movement. Data obtained were analyzed using DEA model software solver pro. Version 13.0 for the output-oriented CCR-model (Constant Return to Scale) in order to examine the overall efficiency of the thirty airports in Nigeria during the 2003-2013 period.

Results of the CCR-model analysis show efficiency scores for the thirty airports in Nigeria indicated in table 1.12. The efficiency indices inclined from 0.0123 to 1 for CCR-model result. The result of the CCR-model analysis indicates that at least 3 different airports are considered to be technically or scale-efficient. The CCR-model analysis further shows that the model is interested in constant return to scale and its efficiency score '1' reveal that three (DMUs) airports are efficient, namely—ABJ DOM, PHC DOM and OSUBI. Among these efficient airports, two of them (ABJ DOM and PHC DOM) are operated by Federal Airport Authority of Nigeria (public), while one (OSUBI) is operated by a private sector (Shell Petroleum Development Company). These efficient airports have a max-efficiency value of 1.0. While the least in technical inefficiency airport from the CCR-model is the KAT. The average efficiency for the 30 DMUs from the CCR-model is 0.4223 (42%).

The policy implication of this research is that the Nigerian airports operated by the Federal Airport Authority of Nigeria have to adopt a policy of improving airports efficiency based on observed correlation metrics and adopting a procedure such as the DEA model in evaluating their technical efficiency, so as to improve the efficiency of the airports. The Federal Airport Authority of Nigeria is the Nigerian airports managerial organization and therefore this organization should adopt a managerially efficient project improvement strategy. The procedure should identify global best practices in airports which could be used to benchmark the operations of the less efficient Nigerian peers for productivity improvement and general efficiency. Further research in this area is needed for improvement of the critical findings and contributions of the present research in the sustainable efficiency of Nigerian Airports' service delivery projects.

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