MEASURING EFFICIENCY OF STATIONS IN AN AIRLINE NETWORK: AN APPLICATION OF DATA ENVELOPMENT ANALYSIS

Salleh, Mad Ithnin
Jusoh, Osman
Faculty of Business and Economy
University Pendidikan Sultan Idris, Malaysia

ABSTRACT

The competitive nature of the airlines industry has become more intense in recent years. As the competitiveness intensifies, the ability of the firms within the industry to withstand extended periods of productive inefficiency diminishes. Economic theory clearly establishes the importance of measuring efficiency in the airline industry. Those firms with lower level of efficiency are likely to feel the impact of economic dynamics more severely. The concept of efficiency here is the capability of a unit in utilizing input to produce output. In the context of the airline, the units assessed are stations, where they set up their sales office and airport operations. This study attempts to provide a mechanism in measuring relative efficiency and performance of selected five airline stations in a particular continent for the year 2004. This is a hypothetical study using a set of data based on an actual environment. The objective is achieved by establishing a set of efficiency indicator particularly in the aspect of relative efficiency covering both input and output factor of the stations. The input resources are expenditure, number of staff, number of agents and station capacity. The output factors are total revenue, group materialization rate and uplift. The data collected were analyzed using non-parametric technique called Data Envelopment Analysis (DEA). For overall relative efficiency result, three out of five stations i.e. A, D and E were found to be efficient and productive. The three productive stations can serve as efficient reference set for the relatively inefficient station for potential improvement. However, stations B and C were found to be inefficient. This is probably due to their inability to maximize output and minimize input. The present data were collected from one continent only. It is recommended that further research should be conducted involving more stations in other continents. As for data analysis, perhaps using analytical hierarchal process would give a more accurate and interesting result.

Keywords: data envelopment analysis, measuring relative efficiency, airline industry.

INTRODUCTION

The competitive nature of the airlines industry has become more intense in recent years. As the competitiveness intensifies, the ability of the firms within the industry to withstand extended periods of productive inefficiency diminishes. Economic theory clearly establishes the importance of measuring efficiency in the airline industry. Those firms with lower level of efficiency are likely to feel the impact of economic dynamics more severely. The concept of efficiency here is the capability of a unit in utilizing input to produce output. In the context of the airline, the units assessed are stations, where they set up their sales office and airport operations.
This study is based on a hypothetical problem in a major networked airline operating in a global environment. The organization chosen is one of the leading carrier airlines company. It is previously a government agency that was later privatized.

It is the mission of the airline, as a corporation, to provide a transport service that ranks among the best in terms of safety, comfort and punctuality, distinguished and loved for its personal touch and warmth.

In this new age of technology, the airline company is committed to being a carrier as well as a responsible corporate citizen in the global economy. The airline also ventures into a diversified operation that is the human resource development, training, catering, property consultancy and technical ground support for aircrafts. The airline also provides world-class cargo management facilities to meet the needs of their partners.

Problem Statement

As the competitive nature of an airline intensifies, the ability of the firm within the industry to withstand extended periods of productive inefficiency diminishes.

As the competition in the airlines industry become stiffer, an operation research technique shall be applied to help the airline faces this situation. In the current situation the airline tries to assess the performance of its stations the selected continent in terms of relative efficiency measures. This is a hypothetical study using a set of data based on an actual environment.

This paper attempts to discuss the performance assessment particularly on the aspect of relative efficiency to measure the level of productivity via indicator. It compares the efficiency among several units of assessment. This kind of performance measurement will play a role as a management decision-making tool to the management. The performance measurement may help the airline to survive and make profit in the airlines industry.

LITERATURE REVIEW

Analysis of organizations’ performance has been a keynote of the world globalization process. Productivity and efficiency are the two most important concepts in measuring performance. However, these two different concepts have been mistakenly treated the same in most of the literature (Wang, Song and Cullinane, 2003). In 1950 the Organization for European Economic Cooperation (OEEC) developed the following definition of productivity:

“Productivity is the quotient obtained by dividing production by one of the factors of production”.

(OEEC, 1950).

While Steering Committee for the Review of Commonwealth / State Service Provision (1997) indicates productivity as a measure of the physical output produced from the use of a given quantity of inputs.

This definition is easily and very obviously capable of explaining any situation where there is a single output and single input. However, it is more common that production has multiple outputs and inputs, in which case productivity refers to total factor productivity; a productivity measure involving all factors of production. In this way, in order to calculate productivity we have to know and measure the different variables, which make up both the inputs and the outputs. To find them is, in practice, a very complex task since the proportions of the outputs may change with time or vary from one company to another, making it difficult to define total output. This is because it would be difficult for an industry to have only a single output.
While according to Review of Commonwealth / State Service Provision (1997) efficiency is described as the success in 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 a given quality. This can be assessed in terms of technical or productive, allocative and dynamic efficiency.

Farrell (1957) proposed that the efficiency of a firm consist of two components: technical or productive efficiency, whereby the ability of a firm to obtain maximal output from a given set of inputs and allocative efficiency, which will reflect the ability of a firm to use the inputs in optimal proportions, given their respective price. These two measures are then combined to provide a measure of total economic efficiency. While Wang, Song and Cullinane, (2003) defined efficiency as a relative productivity over time or space, or both. It can be concluded that productivity is an absolute concept, measured by the ratio of outputs to inputs, while efficiency is a relative concept, measured by comparing the actual ratio of outputs to inputs with the optimal ratio of outputs to inputs.

Two types of efficiency measures are usually distinguished at the firm level in the production economics (Sengupta,1995). One is technical or productive efficiency, which measures the firm’s success in producing maximum output from a given set of inputs (Steering Committee for the Review of Commonwealth/State Service Provision, 1997). The other is the price or allocative efficiency, which measures a firm’s success in choosing an optimal set of inputs with a given set of input prices. The long term survival and prosperity of a firm in airlines industry depends on large measure of it ability to generate revenue using as few resources as possible which are related to productive efficient term.

This productive efficiency improves firm ability of the firm to sell its product and services at a price at least equivalent to the cost required to produce them (Owen, 2004). Inefficient production results in increased cost and reduced profit potential, is indicative of poor economic allocation of resource, and likely to attract more efficient producer to the market.

In relation to productivity improvement one need to develop measure of both efficiency and effectiveness, and then uses both measures to monitor productivity improvement. Based on some indicator, for example, the performance of any unit can be detected and then comparison for rating purposes can be made. This can lead to a new term known as performance indicator.

According to Gaither et al (1994) specifically performance indicators can be defined properly as the concrete information about a condition or result of publication that is regularly produced, publicly reported and systematically used for planning, monitoring, or allocating resource at the state of system level. As reported by Norshahida (2004) other various definitions of performance indicator are:

Performance indicator which are numerical values that provides a measurement value for assessing the quantitative or qualitative performance of system,

They are indicators in which a value judgment is involved, when indicator show a differences in one direction, this mean that the situation is better and if the indicator shows a differences in the opposite direction, the situation is less favorable,

Indicators are signal derived from database or from opinion data, which indicates the need to explore deviation from either normative or other pre-selected levels of activity or performances,

Indicator monitor developments or performance, signals the need for further examination of issues or conditions, or assist in assessing quality,

An authoritative measure, usually in quantitative form, of an attribute of an activity of an institution. The measure may be ordinal or cardinal, absolute or comparative. In thus includes the medical application of formulate and such informal and subjective procedure as peer evaluation or reputation ranking
There are many performance indicators that are used in airlines industry (National Economic Research Associates, 2001). Minwir (1999) indicated that the deterministic methods to the measurement of productive efficiency often involve mathematical programming (non-parametric) models, including data envelopment analysis, where no assumptions are made about the form of the production function. Instead, a best-practice function is empirically built from observed inputs and outputs. In contrast to the parametric approach, the concern here is not in comparing each unit with some unspecified average but in establishing norms of best achieved practice to which those units that fall short can aspire (Norman and Stoker, 1991; Lovell, 1993).

The basic step in assessing the performance of the airlines industry is to consider two basic elements: the input and the output factors. Input factors are defined as limited amount of resources to produce a maximum amount of output. The output factors are the consequences, outcomes or the products as the result of utilizing limited of resources. To identify the inputs and the output in assessment is difficult and subjective (Norshahida, 2004). The input should capture all resources, which will creates an impact on the outputs. The output on the other hand should reflect all useful outcomes on which we wish to assess how efficiently each unit is handling the transformation process (that is the process of transformation input into output) when compared to another unit engaged in a similar process.

Particularly in research area, there are various factors to be considered as the output and input. As mentioned by Gillen and Lall (1997) the outputs of the top 30 airports in United State were: number of passenger, weight of cargo, number of air carrier movements and number of commuter movement. Input factors for top 30 airports in United State were: number of runaway, number of gates; terminal area; total number of airport employee; number of baggage collection belts; number of public parking space; airport area and runaway area. Meanwhile Parker (1999) has used passenger number and cargo and mail handled as the output of the airport on United Kingdom. While inputs of the airport at United Kingdom are: employment, capital estimated and other cost, i.e. total cost less labor and capital costs.

According to Martin and Roman (2001), in assessing 37 airports at Spanish have identified output factors as air traffic movement, number of passengers and number of tones or cargo transported in each airport. Inputs for these airports were measured as expenditures and were classified according to labor, capital and materials. While Sarkis (2000) wrote, in analyzing the operational efficiency of 44 major airports in United State, the output factors were measured in terms of operating revenue generated, aircraft movement, general aviation movements, the number of passenger and the amount of cargo. Input factors comprises of financial cost, labor and the number of gates and runaway.

A few meaningful factors have been identified to be included in the study and are found available. The following table shows the input and output factors that will be used in the context of the airline’s stations in the selected continent:
RESEARCH METHODOLOGY

Using DEA model, researchers are required to formulate the problem into mathematical expression. The mathematical formulation of DEA technique consists in the solution of a set of linear programming models (Charnes, Cooper, and Rhodes, 1978) aimed at maximizing the efficiency of each DMU, $h_k$. For $k = 1, 2, \ldots, S$

$$\begin{align*}
\text{Max } h_k &= \frac{\sum_{r=1}^{n} U_r Y_{rk}}{\sum_{i=1}^{m} V_i X_{ik}} \\
\sum_{r=1}^{m} V_i X_{ik} &\leq 1 \\
\sum_{r=1}^{n} U_r Y_{rk} &\leq \sum_{i=1}^{m} V_i X_{ik} \\
U_r, V_i &\geq 0; r = 1, \ldots, i = 1, \ldots, m
\end{align*}$$

Where $S$ is the number of DMUs, $m$ is the number of input variables; $X_{ik}$ is the amount of input $i$ used by DMU $k$; $n$ is the number of output variables, $X_{rk}$ is the amount of output $r$ generated by DMU $k$; $V_i$ is the weight associated with input $i$ and $U_r$ is the weight associated with output $r$.

The relative efficiency score of a DMU will depend upon the choice of weight $V_i$ and $U_r$. In the traditional basic efficiency measure, the weights are assumed to be uniform across the input and output variables. DEA, however select the weight that maximizes each DMU’s relative efficiency score under the condition that no weight is negative, and that resulting efficiency ratio must not exceed one. For each DMU,
DEA will choose those weights that would maximize the relative efficiency score in relation to other DMUs (Saha and Ravisankar, 2000).

The model presented above is equivalent to a set of traditional linear programming models in which the DMUs input and output weights are treated as the decision variables. For \( k = 1, 2, \ldots, S \)

Maximize  

\[
\mathbf{h}_k = \sum_{r=1}^{s} Y_{rk} U_r
\]  

Subject to:  

\[
\sum_{r=1}^{s} Y_{rk} U_r - \sum_{i=1}^{m} X_{ik} V_i \leq 0 ; k = 1, \ldots, n
\]

\[
\sum_{i=1}^{m} X_{ik} V_i = 1
\]

\[
U_r \geq 0 ; r = 1, \ldots, s
\]

\[
V_i \geq 0 ; i = 1, \ldots, m
\]

The score for each unit is obtained by solving \( n \) such standard linear programs, one for each unit. In computing relative efficiency for the five airline stations (refer Figure 1) the inputs factor include: (a) Expenditure, (b) Number of staffs (c), Number of Agents and (d) Capacity, while the output factor including (a) Total revenue, (b) Group materialization rate and (c) Uplift. In such resource-based and outcome-focused evaluation, the participating units that can maximize their outcomes based on the level of resources available to them will be considered as the “best practice” unit. In this context a unit is efficient when the value of relative efficiency ratio \( h_k = 1 \), whereby \( h_k \) is the relative efficiency indicator. On the other hand if the value of \( h_k < 1 \), the unit is said to be inefficient.

**FINDING AND CONCLUSION**

<table>
<thead>
<tr>
<th>Unit</th>
<th>Station</th>
<th>First half of 2004 – Relative efficiency ((h_k))</th>
<th>Second half of 2004 – Relative efficiency ((h_k))</th>
<th>Position</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Station A</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Station D</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>Station E</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>Station C</td>
<td>1</td>
<td>0.8469745</td>
<td>4</td>
</tr>
<tr>
<td>5</td>
<td>Station B</td>
<td>1</td>
<td>0.8761932</td>
<td>5</td>
</tr>
</tbody>
</table>

Table 1.2. **The overall Performance Ranking**
It was found that stations A, D, E were efficient and productive throughout the year. These three stations had rating of 100 percent \((h^*=1.00)\). However the station B and E were found to be inefficient and unproductive for the second half of the year 2004. These two units had a rating of less than 100 percent \((h^*<1.00)\) Thus it can be concluded that the airlines could make substantial productivity improvement to the two inefficient participating unit.

**Conclusion**

Data Envelopment Analysis (DEA) method has successfully compute the relative efficiencies for selected five of the airline stations which consists the input and output factors. Overall with DEA method, in the first half of year 2004 all of the selected five airline stations were found efficient. While in the second half of year 2004, two out of five stations were found to be less efficient and they were Station C and Station B. They are also known as the less-productive stations.

Data Envelopment Analysis (DEA) also identified three of the airline stations, which can serve as efficiency reference set for the relatively inefficient station for potential improvements. The three stations that serve as efficiency reference sets are Station D, Station A and Station E, which can help two other stations (Station C and Station B) that were found less efficient for the possible improvement. The three efficient stations, which serves as an efficient reference set can disseminate their efficient operating practice to all other station so that they will improve the airline’s productivity.

Number of no show criteria has been identified by the airline as one of the major output that should be included in the data Envelopment Analysis (DEA) method. To show the significance of the criteria towards the airline’s efficiency the Analytic Hierarchy Process has been applied in order to obtain the prioritized ranking of the decision alternatives based on the overall preferences expressed by the decision maker. From this method we can conclude that number of no show criteria is not significant to be included in the Data Envelopment Analysis (DEA) method for computing efficiency. From the AHP result we can see that number of no show criteria is the least important criterion for the airline in selecting best station.

However, it should be understood that AHP is not a method for measuring efficiency but it is a method that produces prioritized ranking on each of the decision alternatives based on the overall preferences by the decision maker.

**Discussion and recommendation**

The objective behind contact with relatively efficient was to identify which managerial practices that have been adopted may serve as reference for the group of station considered relatively less efficient. These were called the "best-practices". Yet for the group of the relatively less efficient stores, information was obtained to compare the way those practices are held, whether they differ or not from those of the 100 percent relatively efficient station.

**Identifying Potential Transformation for Achieving Efficiency**

Focusing on the less efficient unit, possible augmentation outputs and inputs reduction can be identified. This is based on the DEA model (1) and (2). To achieve the efficiency rating 100 percent \((h^*_k = 1.00)\), for the less efficient units, the value for input and output variables in the output variables function can be adjusted until the relative efficiency indicator \(h^*_k\) achieves 1.00. The augmentation in output and input reduction can help organization to achieve the efficiency rating of 100 percent \((h^*_k = 1.00)\).

However in this study, in order for a unit to be efficient, the increase in output level will be only taken into account and the input used is unchanged.
Based on Table 11, both of inefficient stations require an increment for at least one output to be efficient. As an example, in order Station B to be efficient or productive, it has to increase its total revenue to RM 150,000,000 and increase their total uplift to RM 85,000. While for Station C to be efficient it has to increase their total revenue to RM 45,000,000 and increase their uplift to RM 45,000. But in both suggestions we need to take into consideration that the input used is unchanged. If the airline has considered the suggested output augmentation, both stations can achieve efficiency rating of 100 percent ($h_k = 1.00$).

For further research it is recommended that study be conducted using AHP and data should have been taken from more stations from different continents.

Table 11. Suggested Output Augmentation

<table>
<thead>
<tr>
<th>Station</th>
<th>Observed output</th>
<th>Possible Augmentation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Y1(000)</td>
<td>Y2</td>
</tr>
<tr>
<td>Station B</td>
<td>129734</td>
<td>205</td>
</tr>
<tr>
<td>Station C</td>
<td>32933.4</td>
<td>260.5</td>
</tr>
</tbody>
</table>
REFERENCES


Bowlin, W.F., (1995), Measuring Performance: An Introduction to Data Envelopment Analysis (DEA), Department of Accounting, University of Northern Iowa


Graham, A., (2000), Efficiency Measurement For Airport, Transport Studies Group, University of Westminster


Poitras, G., Tongzon, J & Li, H (1996), Measuring Port Efficiency:An Application of Data Envelopment Analysis, Department of Economics and Statistics, National University of Singapore

Rickards, C., (2003), Setting Benchmarks and Evaluating Balanced Scorecards With Data Envelopment Analysis, Benchmarking; An International Journal, 10(23), pp100-113

Sengupta, J.K.,(1995), Dynamic Efficiency Model Using Data Envelopment Analysis, Department of Economics, University of California, Santa Barbara, California


Wang, T.F., Song, D.W., & Cullinane, K., The Applicability Data Envelopment Analysis To Efficiency Measurement Of Container Port, Department of Shipping and Transport Logistics, University Hung Hom Kowloon

Wen, H.J., Lim, B., & Huang, H.L., (2003), Measuring E-Commerce Efficiency: A Data Envelopment Analysis (DEA) Approach, Industrial Management And Data Systems , 103(9),pp703-710