The Analysis of Airport Operational Performance Case Study: Chiang Mai International Airport, Thailand

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***Abstract*---The purpose of this study is to determine which of the airport has the best performance in term of the number of passengers processed, in order to improve the airport operational performance. Data envelopment analysis (DEA) was employed to assess the operational performance of 19 airports in Asean plus 3. The methodology reflected which factors that was significant and related to the operational performance of the airport. There were 5 inputs (Terminal size, Number of runways, Lengths of runways, Number of gates and Check-in desks) and 1 output (Passenger movement) was deliberated in this study. The result of this study had shown that there were some major airports that inefficiency operated, due to using inefficiency input. Chiang Mai International Airport was also inefficient. The paper has done slightly further on sensitivity analysis, in order to evaluate the input-output of Chiang Mai International Airport. It presented that each time the input factors have changed, it made an impact to the efficiency score. The information of this study could support the Airports of Thailand to make decision about the future of Chiang Mai International Airport.**

Keywords-Air transportation; Operational performance measurement; Data Envelopment Analysis; Sensitivity Analysis

I. INTRODUCTION

At the very beginning of 20th century, Air industry started to aggressively competing one another. Not only Airline Company, but also Airport itself tries to play against others to survive in the rival. Airport is the place that the entire journal begins. It plays an important role to deliver one of the most essential transportation modes around the world. However, in order to be competitive, Airport aims to have an efficiency and effectiveness in all kind of activities. Passenger terminal, runways, employees, check-in desks etc. are responsible for producing a better higher service quality than other potential airports. To have incomparably satisfied customers, airport would have to supply sufficient runways and terminal capacity to stay away from the delays at even the demanding period. Figure 1 shows the numbers of passengers carried by air transport are slightly increasing year by year. According to [6], the numbers of passenger will double increases in upcoming year 2030. Many airports have been built and expanded in Asia by the side of economic development. To ensure that the airport will have the superlative performance, as well as, can generate profitability, Airport industry may needs to constantly monitor their performance, in order to increase the market force and more than that a competitive

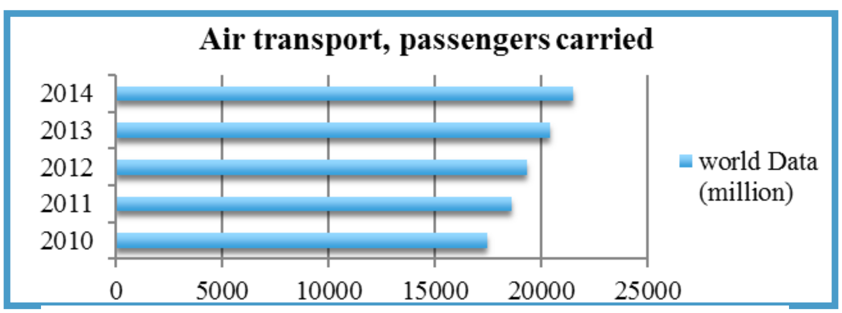

Figure 1: Number of passenger carried by Air transport

environment. The competitive environment of the aviation industry basically is about greater market mobility and the freedom to link and align. A great deal of effort and resources have been broadened in developing a performance measurement for carriers in the different modes of transportation [4]. The purpose of this study is to produce an inclusive evaluation from sources of efficiencies related to operation scale and input deployments that contribute to the output of an airport. The supporting tool used in this study is Data Envelopment Analysis (DEA). It is workable to reveal the best link between airport infrastructure and passenger movement.

II. LITERATURE REVIEW

Data Envelopment Analysis (DEA)

Data Envelopment Analysis (DEA) model was formulated in the 1970s [2]. It involves the use of linear programming methods to construct a non-parametric piece-wise frontier over the data. Efficiency measures are then calculated relative to this frontier. The comprehensive treatments of the methodology are available whether Seiford and Thrall (1990), Lovell (1993), Ali and Seiford (1993), Charnes et al. (1995), or Thanassoulis (2001). The model makes use of mathematical programming based on the multiple inputs and multiple outputs to estimate the relative efficiency of multiple Decision Making Units (DMUs). This paper operated number of input and output factors that represent the resources utilized by airports. Productivity in air industry has been restricted to the organizations that use the services of airport and on general transportation infrastructure [11]. According to reference [11], they applied DEA method to consider a comparative productivity value to determine a unit's relative efficiency score. DEA method and other productivity measurement have appeared in many researches area, including air performance measurement. Reference [5] worked on the total factor productivity measurement to conclude an analysis of airport measurement. Reference [4] stated that the use of DEA for evaluation of performance is one of the great choices. They concluded that the terminal efficiency is improved by expanding the number of boarding gates and managing in the way that can effective utilized. This paper developed the work shown that DEA can use to benchmark the airport operational performance. Reference [10] also has utilized DEA method for evaluating the airport performance. The paper focused on tree factors that might impact the airport operation performance. This paper also developed the work homogeneously as [10], but differently evaluating by factors. Reference [9] compared the European airports by using DEA method. They determined whether there was a variety of return-to-scale evaluation of the airports. The return-to-scale can measure by comparing CCR and VRS. Reference [3] studied 35 Brazilian domestic airports implementing the DEA technique to evaluate capacity efficiency in term of passenger utilization with operation resources. They also pointed out that the result of the model could gave the big picture of the action necessary to keep up with the appropriate service level in the airport system. Reference [12] studied the validity of criticisms, such as inefficient public investment or transportation infrastructure, by weighting the efficiency of Japanese airports and organizing comparative analysis. Reference [8] used DEA to analyze the operational performance of 20 major airports around the world. They agreed that the hub, location of the airport, and the economic growth rate are influence to the operational airport performance. Moreover, the model is also suitable for evaluation the operation performance because the reference set in DEA model can be used for benchmarking purpose [8]. Reference [7] studied different dimensions of operational efficiency in the major Asia Pacific airports using DEA. Based on the assumption, the ranked of the airport do not consistent. It varied by different dimensions. Most of these studies dealt with the relation of Airport's input-output, fair differed in their factors.

DEA efficiency measurement

Basic DEA model: This paper applied DEA model according to [11] and [12]. The ratio-based DEA productivity models for a given decision-making units (DMUs) use ratios based on the amount of output per given set of inputs. This paper the DEMs is Airport. Reference [1] developed DEA model, in order to maximize the efficiency value set of a test airport from among a reference set of airport. We adopt their model to our paper:

$$\text{Maximize } \frac{\sum_{i=1}^{M} u_i y_{i0}}{\sum_{j=1}^{N} u_j x_{j0}} \tag{1}$$

$$\text{Subject to: } \frac{\sum_{i=1}^{M} u_i y_{il}}{\sum_{j=1}^{N} v_j x_{jl}} \leq 1 \qquad \forall\, l = 1,\ldots,L \tag{2}$$

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$$u_{kx},\ v_{ky} \geq 0 \qquad \forall\ i = 1,\ldots M,\ \forall\ j = 1,\ldots N$$

Where L is the number of reference airports, y_{il} and x_j are the i^{th} output and j^{th} input of the l^{th} airport respectively, and *M* and *N* are the number of outputs and inputs respectively. The following is the reduction form of the above maximization problem for DEA efficiency of each airport [12]:

Min h_0

Subject to: $\sum_{i=1}^{L} \lambda_l y_{il} = y_{i0} \qquad \forall\ i = 1,\ldots M \qquad (3)$

$$\sum_{i=1}^{L} \lambda_l y_{il} = h_0\, x_{jt} \qquad \forall\ j = 1,\ldots N \qquad (4)$$

$$\sum_{i=1}^{L} \lambda_l = 1 \qquad (5)$$

$$\lambda_1, \ldots, \lambda_{L,} = h_0 \geq 0$$

The answer of this mathematical model -- h_0 indicates ''input-oriented'' efficiency of each airport. The input-oriented efficiency measurement explains how efficiently inputs are used for the given output level. Our paper also concentrated on input-oriented DEA efficiency. According to [1], VRS-DEA efficiency measured as h_0 specifies only technical efficiency and does not consist of scale efficiency. However, according to [12], there is a coincidental that with the VRS DEA model, the scale efficiency is underestimated. Scale efficiency is evaluated by running DEA under two different scenarios: First, Run DEA with constant returns to scale (CRS) – run the LP problems listed mentioned above. The second scenario is run DEA with variable returns to scale (VRS) – run the same LP problems with an additional constraint: I1'λ = 1, as the (5). After running the model, we will get the ratios of TE (Technical Efficiency) that offer a scale efficiency measurement.

III. METHODOLOGY

Theoretical methodology of this study is built on the key performance areas and key performance indicators of airport operational performance. The information utilized in this study was retrieved from the Airports Council International (ACI) and also directly from the airport. The performance measurement of the airport can be divided into several sets of measurement, for instance, financial, commercial and operational performance measure. There are commonly used to evaluate the airport ability.

Airport's Data Interpretation

The data of 19 International Airports, located in Asean plus 3 countries in the year 2014 were collected. Table 1 show the list of the selected airport. The airport industry is various in many aspects of quality distinction, different ownership, regulation, variety of service and operating characteristics. Because of these reasons, Airport evaluation is challenging, especially when compare with the one that has a very good response. The data set contains one output which is Number of passenger. For the input data, there are five factors that are considered in this study: Terminal size, Number of runways, Length of runway, Number of gates, and Check-in desks. The inputs that used in the analysis are the factors that are common to all airports. As for the Terminal size input variable, we measured by using the total floor area of the terminal building in square meters. Passenger terminals are vital component of airport infrastructure. The size of the terminal is very critical to handle passenger smoothly, including passenger and cargo accessibility or passenger comfort. As the Number of runways, it is significant for speedy taking off and landing and reducing number of queue on the air. As for the Length of runway, we use the total length of runways in meters. To have a better facility to serve the airline, the airport should be able to facilitate large aircraft types such as Airbus 380. The more airlines bring passengers to the airport, the more airport tax and other incomes received by the airport. As for the Number of gates, it accommodate airline to park the aircraft right in front of the boarding bridge gate. Therefore, passenger can easily move into the aircraft. As for the Check-in desks, passenger does not need to wait in the line for long time to check in. Moreover, many check-in desks could reduce passenger congestion. We considered only the operation performance of the airport because it was directly connected to passenger and airline satisfaction, moreover, because of the data collection difficulty. Financial measurement, therefore, was not considered in this paper.

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Table 1: Airports list

No.	Airport	Country	IATA Code	Note
1	Singapore Changi Airport	singapore	SIN	The top Skytrax world airport 2014
2	Incheon International Airport	Korea Rep.	ICN	
3	Hong Kong International Airport	Hong Kong	HKG	
4	Tokyo International Airport Haneda	Japan	HND	
5	Chubu Centrair International Airport, Nagoya	Japan	NGO	
6	Chengdu Shuangliu International Airport	China	CTU	Random selection
7	Gimhae International Airport	South Korea	PUS	
8	Kansai International Airport, Osaka	Japan	KIX	
9	Kuala Lumpur International Airport	Malaysia	KUL	
10	Ngurah Rai International Airport, Denpasar	Indonesia	DPS	
11	Noibai International Airport, Hanoi	Vietnam	HAN	
12	Penang International Airport, Penang	Malaysia	PEN	
13	Shanghai Pudong International Airport	China	PVG	
14	Tan Son Nhat International Airport, Saigon	Vietnam	SGN	
15	Xiamen International Airport	China	XMN	
16	Yangon International Airport	Myanmar	RGN	
17	Kunming International Airport	China	KMG	
18	Soekarno-Hata International Airport, Jakarta	Indonesia	CGK	
19	Chiang Mai International Airport	Thailand	CNX	Case study

The solution indicated the input-oriented efficiency of each airport. The measure of input-oriented efficiency specified how the input will give an impact to the output level. DEA can be piloted under the assumption of constant returns to scale (CRS) or variable returns to scale (VRS). This paper compared constant-return to scale (CRS) with variable-return to scale (VRS). If the result of both scales is not equivalent thus, the airport is insufficient to provide high operational performance. DEA allocate a score of 1 to a unit only when evaluations with other related units do not provide indication of inefficiency in the use of input or output. A score less than 1 means that there are inefficient units occurred. The CRS assumption is only suitable when all firms are operating at an optimal scale, whereas, The VRS assumption is appropriate when the firms are not operating at an optimal scale. The scale efficiency can be calculated by approximating both the CRS and VRS models and considering at the difference in scores

The score on both CRS and VRS are presented in the table 2: DEA efficiency score. We used the DEAP 2.1 software to analyze the results. DEAP 2.1 is used to construct DEA frontiers for the calculation of technical and cost efficiencies and also for the calculation of Malmquist TFP (Total Factor Productivity) Indices. However, in this paper, we only focused on the calculation of technical efficiency and u the result to the scale efficiency. This can generate the scale efficiency which is partly answering the question.

Table 2: DEA efficiency scores

Airport	IATA Code	CRS(TE)	VRS(TE)	Scale
Singapore Changi Airport	SIN	0.749	0.848	0.883
Incheon International Airport	ICN	0.637	0.826	0.771
Hong Kong International Airport	HKG	1.000	1.000	1.000
Tokyo International Airport Haneda	HND	1.000	1.000	1.000
Chubu Centrair International Airport, Nagoya	NGO	0.469	1.000	0.496
Chengdu Shuangliu International Airport	CTU	0.719	0.929	0.774
Gimhae International Airport	PUS	0.544	1.000	0.544
Kansai International Airport, Osaka	KIX	0.436	0.786	0.556
Kuala Lumpur International Airport	KUL	0.714	0.818	0.873

Ngurah Rai International Airport, Denpasar	DPS	0.632	1.000	0.632
Noibai International Airport, Hanoi	HAN	0.485	0.840	0.577
Penang International Airport, Penang	PEN	0.377	1.000	0.377
Shanghai Pudong International Airport	PVG	0.639	0.816	0.783
Tan Son Nhat International Airport, Saigon	SGN	1.00	1.000	1.000
Xiamen International Airport	XMN	0.620	0.752	0.824
Yangon International Airport	RGN	1.000	1.000	1.000
Kunming International Airport	KMG	1.000	1.000	1.000
Soekarno-Hata International Airport, Jakarta	CGK	0.307	1.000	0.307
Chiang Mai International Airport	CNX	0.602	1.000	0.602

CRSTE-DEA efficiency

There are 19 Asean plus 3's airport considered in this paper. Table 2 represented the result of the model by using DEAP 2.1 software. The results were the input-oriented efficiency measurement. It was composed of CRSTE, VRSTE-DEA efficiency, and Score efficiency. Based on the result, there were 5 out of 19 airports which were allocated the CRSTE-DEA score of 1, meaning that they recorded as the efficient airports. Hong Kong International Airport and Tokyo International Airport Haneda yielded the full score, which may contradict that they are suffering from the congestion (For Hon Kong, 63,148,379 passengers with 846,000 square meter terminal size. For Haneda, 72,826,862 passengers in year 2014 with only 236,000 square meter terminal size). This could lead to the lower service quality in the future; even the airport itself has high operational performance efficiency. For other three airports which were Tan Son Nhat International Airport, Saigon, Yangon International Airport, and Kunming International Airport, the capacity of each of these airports performs to meet the demand and efficiently utilized. Move to the low efficiency scores, the most inefficient airport of the 19 airports regarding to the CRATE-DEA scores was Soekarno-Hata International Airport, Jakarta. The second most inefficient airport is Penang International Airport, Penang, followed by Kansai International Airport, Osaka, Chubu Centrair International Airport, Nagoya, and Noibai International Airport, Hanoi. One commonality of these airports is their terminal size which is slightly higher than the projected value and this problem may be knocking down their efficiency scores. Chiang Mai International airport, terminal size and check-in desks were the factors that exceeding the projected value, therefore, this leads to the inefficient scores.

VRSTE-DEA efficiency

Airports that generated full score of CRSTE- DEA are efficient in terms of both technical and scale efficiencies; thus, their VRS efficiency scores are also one, by structure. There are some airports whose rankings of CRSTE and VRSTE- DEA efficiencies are moderately different. For example, Penang International Airport, Penang, Soekarno-Hata International Airport, Jakarta, or Chubu Centrair International Airport, Nagoya are given full score for its VRSTE-DEA efficiency, even though it CRSTE-DEA efficiency is ranked at 0.377, 0.307, and 0.469, respectively. Meaning, the ‘‘pure technical efficiencies’’ of these airports evaluated by VRSTE are high, but their ‘‘scale efficiencies’’ are low, which effected in their low rankings in CRSTE-DEA efficiency. Similarity, some other airport such as Singapore Changi Airport or Chiang Mai International Airport are placed at higher position in VRSTE-DEA than in CRATE DEA. However, according to Yoshida and Fujimoto (2004), technical efficiency measured by VRSTE- DEA possibly will be overestimated and thus the scale efficiency is misjudged. Therefore, this paper will simply focus on the CRSTE-DEA efficiency score.

Clarification of the results

As the result presented earlier, we are next analyze Chiang Mai International Airport. The sensitivity analysis is use to conduct in this section. Because of we need to identify how to improve the input factors to have a better efficiency. Sensitivity analysis is the study of how the uncertainty in the output of a mathematical model can be assigned to different sources of uncertainty in its inputs. It is the process of recalculating out comes under alternative assumptions to determine the impact of variable. Moreover, the analysis also increased understanding of the relationships between input and output variables in a system or model. Based on the result above, the following information is the result that retrieved from the DEAP software; CRSTE-DEA efficiency

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Technical efficiency = 0.602
PROJECTION SUMMARY:

	Variable Value		original movement	radial movement	slack value	projected
Passenger	Output	1	6213446.000	0.000	0.000	6213446.000
Terminal size	Input	1	33450.000	-13314.940	0.000	20135.060
No. of runways	Input	2	1.000	-0.398	-0.261	0.341
Lengths of runways	Input	3	3100.000	-1233.970	-1579.361	286.669
No. of gates	Input	4	11.000	-4.379	-3.209	3.413
Check-in desks	Input	5	59.000	-23.485	-34.491	1.024

Figure 2: DEAP result

The result shown that there were some inefficiency input factors which had slightly higher value than the projected value. This impacted the technical efficiency score of Chiang Mai International Airport. We examined variation of technical efficiency by applying the theoretical of sensitivity analysis. We attempted to modify the technical efficiency results. If the output was fixed and the change was in input, the result would change or not. This point will be discussed more below.

Increased the input value by 50%

Technical efficiency = **0.401**
PROJECTION SUMMARY:

Variable value		original movement	radial movement	slack value	projected
Output	1	6213446.000	0.000	0.000	6213446.000
Input	1	50175.000	-30039.940	0.000	20135.060
Input	2	2.000	-1.197	-0.461	0.341
Input	3	4650.000	-2783.970	-1579.361	286.669
Input	4	17.000	-10.178	-3.409	3.413
Input	5	89.000	-53.285	-34.692	1.024

Figure 3: DEAP result (increase)

The result, from the figure 2, present that if we increased the input value, the technical efficiency will decreased automatically.

Decreased the input value by 50%

Technical efficiency = **1.000**
PROJECTION SUMMARY:

Variable value		original movement	radial movement	slack value	projected
Output	1	6213446.000	0.000	0.000	6213446.000
Input	1	15725.000	0.000	0.000	15725.000
Input	2	1.000	0.000	0.000	1.000
Input	3	3100.000	0.000	0.000	3100.000
Input	4	6.000	0.000	0.000	6.000
Input	5	29.000	0.000	0.000	29.000

Figure 4: DEAP result (decrease)

For this case, Number of runways and Length of runways were fixed as the original data because an airport has to have at least one runway with the propel length of runways. The result shown that, if we decreased the rest of input by 50%, the technical efficiency score generated the full score.

IV. CONCLUSION

This paper has adopted the DEA methods in evaluating the efficiency of airports and examined whether the current technical efficiency result of Chiang Mai International Airport are indeed effective or not. The paper has used a data set which consists of 19. Each observation was measured by five inputs (Terminal size, Number of runway, Length of runway, Number of gate, and Check-in desk) and only one output which was Number of passenger. However, this data set does not cover financial data because of data collection difficulty. DEA method presented here that there were relationship between input and output. Additionally, the efficiency measurement through the sensitivity analysis has confirmed that the efficiency of the airport will be lower if the input increased. Meaning, in the situation of the lower input-the higher output, the airport will get the full score if the airport operates in full capacity. As mentioned, the financial indicator was not considered in this paper, therefore, the result lean towards to the use of capacity efficiency and effectiveness. To be more productive, measuring the efficiency by taking the financial into account will be one of the future extension lead of the current research.

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BIOGRAPHY

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