Relative Efficiency Assessment of Projects Using Data Envelopment Analysis

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Abstract- **This paper presents an evaluation of project efficiencies of 39 companies using data Envelopment Analysis. In-Fusion Solutions Sdn. Bhd. was chosen as the case study and data were collected from primary and secondary sources. Primary data were obtained through interviews conducted with personnel from the main office and the company branch in Chennai, India. Secondary data were obtained from published and unpublished documents. Secondary data consisted of information technology completed projects which consist of three inputs and an output. These include labor cost, material cost, project duration, and project contract value. Experimental result was able to identify efficient and inefficient projects. Results obtained showed that there were three efficient projects and the remaining projects were otherwise. Peer group analysis was also conducted to compare projects that are inefficient with efficient projects which belonged to a reference set.**

I. INTRODUCTION

Efficiency measurement is one of the main components in measuring organizational performance. The theory of efficiency is related to the association between resources used and results achieved. Parametric and non-parametric are two approaches that can be used to measure performances. Parametric approaches specify functional form and take into account residual term in the analysis. Non-parametric approaches put less structure on the specification of the best practice frontier and assume no random error [1]. The main difference between both of the approaches is the distribution of data. Parametric approaches concern with normality of the data distribution while non-parametric approaches do not.

Parametric approaches have been used in determining the efficiency of Malaysian commercial banks, Washington State hospitals, Taiwan's international tourist hotel and identifying efficiency in productivity change of Bangladesh crop agriculture etc. [2;3;4;5;6;7]. Non-parametric approaches have been used for measuring efficiency of Malaysian commercial banks, state road transport undertakings and top listed Egyptian companies [8;9;10] and used to improve design of commercial websites [11]. There are many advantages of non-parametric method as compared to the parametric ones. For instance non-parametric approaches are simple and less affected by outliers. These approaches do not require information about the distribution and the variance of the data. Besides that, non-parametric methods do not consider the relationship between the sets of the data. Generally, these methods do not require assumption about the data, and can be used in a broader range of data.

There are many efficiency models available and can be refereed or adapted in the performance measuring process. Models for measuring the efficiency of decision making unit (DMU) within an organization have been proposed by [12], [13] and [14]. However, to the best of our knowledge those models were not able to be used to measure business efficiency for product within an organization or company. This study focuses on developing business efficiency measurement model based on product within an organization using the non-parametric approach. Specifically, the study aims to identify suitable input and output variables, identify projects that are efficient and inefficient, and propose efficient operating costs for inefficient projects. For this study, the term DMU is interchangeable used with product and products are projects undertaken by the company, In-Fusion Solutions Sdn. Bhd. (ISSB). In-Fusion Solutions Sdn. Bhd. has been chosen as a case because it has implemented many projects since its establishment. Furthermore, this study can assist ISSB to monitor the performance of its DMUs and make competitive future plans.

II. CASE BACKGROUD

In-Fusion Solutions Sdn. Bhd. main business is providing solutions for learning and developing new media. ISSB was established in 2002 and its vision is to be the premier information and communication technology company, providing virtual education solutions in a full converging environment. ISSB offers advanced and innovative e-learning solutions to the global community. Currently, the company has a total number of 180 employees.

Primary data were obtained through interviews conducted with several personnel from the main office and the company branch in Chennai, India. Secondary data were obtained from published and unpublished documents. Secondary data consisted of thirty-nine completed projects that were completed. Secondary data were used to study the efficiency of ISSB projects. The data used consisted of three inputs and an output. These include labor cost, material cost, project duration, and project contract value. The three inputs are independent variables while the output is the dependent variable.

In this study, DMUs are projects undertaken by the company. The number of DMUs should be more than or equal to three times the sum of inputs and outputs [15]. From 45 projects, 39 projects were chosen as DMUs and the remaining were not chosen due to data unavailability. The projects are divided into two types: hardware (H) and courseware (C). Three inputs and one output were identified as appropriate for the construction of the project performance model. The inputs were labor costs, material costs and project duration. The output chosen was project contract value.

Labor costs is the total cost (measured in Ringgit Malaysia) of employees involved in the projects. It consists of the sum of salaries of employees involved in completing the projects. The cost of employees involved in the projects is considered as a significant component in measuring the efficiency of projects because employees and projects are dependable to each other. Employees are one of the major components in a project as can only be completed with the cooperation between the employees.

Material cost is another input that is considered significant in developing a project. Material in this context is the total cost of equipments such as the software and hardware used in the projects. The equipment cost includes the cost of equipment rental and the purchase of new equipment. This is also measured in Ringgit Malaysia. The materials used in one project are assumed different from other projects.

Projects duration is the amount of time taken to complete a project and is measured in months. Projects must be completed in a specified time frame and failure to complete projects in time will cause an organization to suffer a loss in profit. Since project completion have direct influence to an organization profit's, it is thus, seen as an important factor and is chosen as an input in the performance model.

The contract value is chosen as the output because it reflects the revenue obtained by the company. There is no other variables/data that can best describe the value of the project. Table 1 below shows a sample of projects with their respective inputs and output while Table 2 shows the descriptive analysis of the projects.

TABLE I
STATISTICS ON PROJECTS

	INPUT			OUTPUT
PROJECT	**LABOR (RM)**	**MATERIAL (RM)**	**PROJECT DURATION (MONTHS)**	**CONTRACT VALUE (RM)**
H1	90,000.00	2,385,547.20	6	2,650,608.00
H2	480,000.00	673,058.00	24	1,346,116.00
H3	6,000.00	895,233.60	1	1,053,216.00
…	…	…	…	…
H9	15,000.00	80,000.00	0.25	149,250.00
H10	15,000.00	63,129.50	0.25	74,270.00
H11	6,000.00	59,376.75	0.25	69,855.00
H12	20,000.00	55,827.20	2	69,784.00
…	…	…	…	…
C6	36,000.00	0.00	12	513,218.00
C7	7,000.00	0.00	2	237,125.00
C8	15,000.00	0.00	2	101,214.00
C9	12,000.00	0.00	3	100,000.00
C10	48,000.00	0.00	12	99,900.00
C11	60,000.00	0.00	6	90,000.00
C12	60,000.00	0.00	6	75,000.00
C13	15,000.00	0.00	3	70,000.00
…	…	…	…	…
C23	9,000.00	0.00	0.5	10,000.00
C24	6,000.00	0.00	3	7,500.00
C25	9,000.00	0.00	2	9,800.00

TABLE II
DESCRIPTIVE ANALYSIS ON PROJECTS' INPUTS AND OUTPUT

	LABOR (RM)	**MATERIAL (RM)**	**PROJECT DURATION (MONTHS)**	**CONTRACT VALUE (RM)**
Maximum	1,190,000.00	2,385,547.20	24	2,650,608.00
Minimum	3,000.00	0.00	0.25	7,500.00
Mean	111,735.84	145,035.75	4.66	328,306.00
Std. Deviation	243,069.04	427,092.22	5.989	538,036.73

III. PROJECT EFFICIENCY MODEL

DEA is a multi-variable model for measuring the relative efficiency of a homogeneous set of DMUs. The efficiency score for each DMU is equal to a ratio of weighted sum of multiple outputs to weighted sum of inputs, and is to be optimized as many times as the total number of DMUs. The efficiency scores are computed in the presence of multiple outputs and inputs simultaneously and the weights for inputs and outputs are not unique. A simple and easy way to measure efficiency of a unit or DMU which have one input and one output is to determine the ratio of output to the input. The general efficiency measure is given by:

$$\text{Efficiency} = \frac{\text{output}}{\text{input}}$$

The efficiency increases as the output value gets larger and the input gets smaller. However, in reality organization operates with the used of multiple inputs to produce multiple outputs. This becomes the drawback of efficiency measure which cannot utilize the situation where there is more than one input or more than one output. To overcome the problem, [16] conducted a study to show that DEA which is a linear programming efficiency model, can be used to measure efficiency that involves multiple inputs and single output. The model proposed by [16], is based on model developed by [17]. In their study, efficiency of each project has to be optimized one by one. The formulation for *j*th project takes the form

$$\text{maximize } \frac{w_1 y_{1j}}{\sum_{i=1}^{3} v_i x_{ij}} \quad (1)$$

subject to

$$\frac{w_1 y_{1j}}{\sum_{i=1}^{3} v_i x_{ij}} \leq 1, \quad \forall j, j = 1, \ldots, 39 \quad (2)$$

$$w_1, v_i \geq 0, \quad (3)$$

where w_1 = weight for output of type 1 of *j*th project,
y_j = amount of output of type 1 of *j*th project,
v_i= weight of input of type *i* of *j*th project,
x_{ij} = amount of input of type *i* of *j*th project,
w_1 and $v_i \geq 0$, for $j = 1\ldots,39$ and $i = 1,\ldots,3$.

Objective function (1) and constraints (2) and (3) composed of fractions and need to be transformed into linear form so that the model can be solved using simple linear programming such as simplex.

This paper further enhanced the analysis on relative efficiency scores and peer group anlaysis of the projects undertaken by ISSB, reported in [16].

IV. Experimental Results

The performance model was used to evaluate projects efficiency, peer group analysis and projection for inefficient projects. The results are described in the following sections.

A. *Projects' Efficiency*

Figure 1 partially depicts efficient projects (score = 1) and inefficient projects (score < 1) ranked by efficiency scores. From the graph, three projects, H3, H9 and C7 are considered as efficient. Others (36 projects) are inefficient with scores ranging from 0.037 to 0.984. Project C24 is the most inefficient project with the lowest efficiency score which is 0.0367.

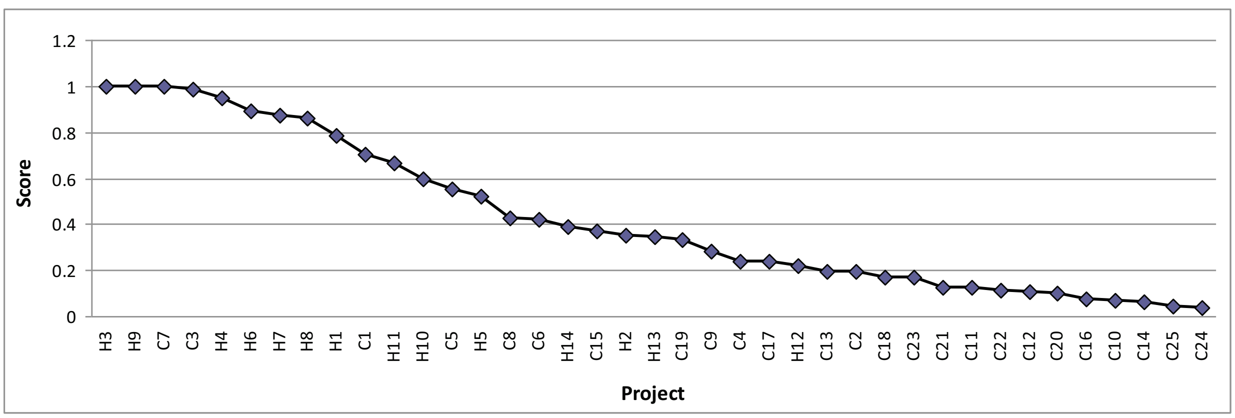

Fig. 1. Projects ranked by relative efficiency scores

Project inefficiency occurs because there is no balance between the three inputs used with the output produced. Project C24 is the project with the lowest contract value but the cost of labor used is high and the project cost is relatively high (Table 1). The contract value for project C24 (RM 7,500.00) is the lowest contract value among all the projects but the cost of labor is high which is RM 6000.00. The same situation took place for other inefficient projects but with relatively different degree of seriousness. On the contrary, the inputs used by the efficient projects are relatively balance with the output, the projects contract value. For example, in project H3, the contract value for the project is RM 1,053,216.00. This means that project H3 used minimum cost of labor and material and completed the project in a period of only 1 month.

Meanwhile, from the input labor perspective, the cost of labor for project H12 (RM 20,000.00) is higher than the cost of labor for project H9 (RM 15,000.00) but the contract value for project H12 is smaller compared to the contract value for project H9 (RM 149,250.00) which is RM 69,784.00. This condition allows project H9 (efficiency score=1) to be more efficient relatively compared to project H12 (efficiency score= 0.21767) which ranked 25th in the efficiency score ranking.

From the input of material view, the cost of material for project H4 (RM 950,000.00) is higher than the cost of material used for project H3 (RM 895,234.00) but the contract value for project H4 is smaller compared to the contract value for project H3 (RM 1,053,216.00) which is 1,000,000.00. This makes H3 to be efficient and ranked first as compared to H4, which is inefficient and ranked lower than H3, even though, the cost of labor and project durations for the two projects are the same.

Meanwhile, from input project duration perspective, for project C12, it took 6 months which is a longer time to complete compared to project C7 which needed only 2 months to finish. The cost of labor of RM 60,000.00 with project duration of 6 months yielded project C12 contract value of RM 75,000.00 as compared to the project C7 which yielded much higher contract value of RM 237,125.00 but with less cost of labor (RM 7,000.00) and less project duration (2 months). This situation allows project C7 to be at a better position than project C12.

In summary, we can say that projects H3, H9, and C7 with relative efficiency scores of 1 are classified as efficient. These projects could balance the input used with output produced and were able to produce maximum output from a given set of inputs or to use a combination of minimum inputs to achieve desired output. They are also able to use material and project duration (inputs) efficiently in the production of output.

Other 36 projects with relative efficiency scores less than 1 are classified as inefficient. The reasons are these projects had unbalance inputs and output and used excess resources in order to produce the output. They were not using labor, material and project duration (inputs) efficiently in the production of output. The duration of project to complete was always longer but the contract values were not high.

The efficiency distribution by project type is also examined as depicted in Table 3. The average scores indicate clearly that the type of project is an important factor in achieving good score.

TABLE III
EFFICIENCY COMPARISONS BY PROJECT TYPE

Project type	No of projects	Average score	Standard deviation
Hardware	14	0.676	0.27
Courseware	25	0.285	0.27

The relationship between contract vale and the efficiency is also investigated. The result of the average efficiencies is as shown in Table 4 where it can be seen that high efficiency is obtained for contact value which is more than RM 1 million. The result is again portrayed in Fig. 2

TABLE IV
AVERAGE EFFICIENCY SCORE BY CONTACT VALUE

Contract value	Average score	No of projects
< 0.5 M	0.355	30
0.5 - < 1.0 M	0.350	3
1.0 M - < 1.5 M	0.797	5
1.5 M - < 2.0 M	0	0
> 2.0 M	0.788	1

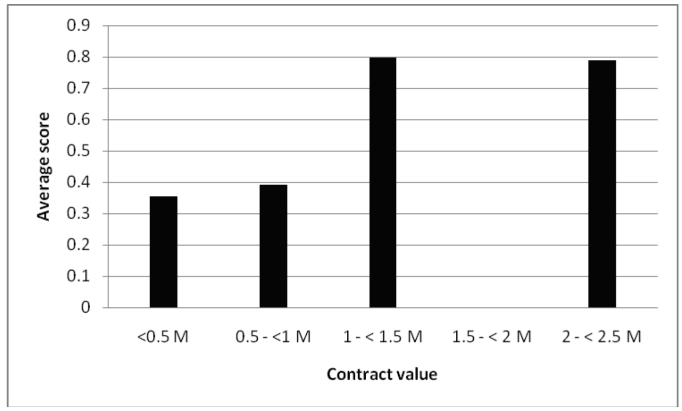

Fig. 2. Effect of contract value on relative efficiency scores

B. *Peer Group Analysis*

Peer group analysis was conducted to compare projects that are inefficient with efficient projects which belonged to a reference set, so that the performance of the inefficient units can be improved [18;19;20]. Table 5 shows the reference set defined by projects C7, H3 and H9 closest to its respective evaluated inefficient projects which have similar mixes of inputs and output.

TABLE V
REFERENCE SET FOR INEFFICIENT PROJECTS

Reference Set (Efficient project)	Inefficient Projects	Total
C7	C1,C2, C3, C4, C5, C6, C8, C9, C10, C11, C12, C13, C14, C15, C16, C17, C18, C19, C20,C21, C22, C23, C24, C25, H1, H2, H4, H5, H6, H7, H8, H10, H11, H13, H14	35
H3	C3, C20, H1, H4, H6, H7, H8, H11	8
H9	C5, H1, H2, H6, H7, H8, H10, H11, H12, H13, H14	11

The reference sets for inefficient projects are chosen because they have the same pattern factor value and not because they have the same characteristics [21]. This reference set made up an efficient frontier or envelopment surface and reacted as the best practice projects or the bench marked units. Even though all of the three efficient projects have the same score of one, but based on Table 5, it can said that project C7 is the best because it is the most frequently referred project (35 times. The second and third best projects are H9 and H3 which are referred 11 times and 8 times respectively.

V. CONCLUSION

DEA is utilized in measuring the efficiency of the selected projects due to its capability of considering multiple inputs and outputs simultaneously. However, in order to have a different view about the efficiency of business units, another non-parametric method such as artificial neural network could be utilized. The usage of two different methods allows the researchers to make comparison and give different suggestions to the management to improve the business units' performance.

The business efficiency model can be generalized by testing to other IT company with the same business nature regardless of the number of input and output. The model is simple yet practical in implementation. The projects which act as the decision making unit can later be used to determine the efficiency of the company department/unit that housed the projects. It is also suggested that the model can be improved by including one or two more relevant inputs or by identifying other outputs.

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