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Maintenance performance of Malaysia's automotive sector: A case study

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Abstract

Today, maintenance is considered as an indispensable part of the business process. Efficiency and effectiveness of the maintenance function will affect the performance of the production system and the capability of the machine to produce quality products. One of the excellent tools for the benchmarking process is Data Envelopment Analysis (DEA). DEA has been widely applied to perform efficiency analysis in many sectors. In this research, we apply DEA to measure maintenance performance for one of the major automotive manufacturer in Malaysia. The assessment was performed in two trials to demonstrate the importance of identifying the inputs and outputs and to determine the effect of certain input. The assessment was conducted based on general model for maintenance with the appropriate inputs (cause) are man, machine, money, training, and time, or "3M2T" and the outputs (affect) are production, quality, cost, delivery, safety, morale, and time, or "PQCDSMT".

Keyword: Data Envelopment Analysis; performance measurement; Total Productive Maintenance.

1. Introduction

Today, maintenance is considered as an indispensable part of the business process due to complexity of manufacturing process to meet the high speeds changing in advanced technologies and customer demands. According to Alsyouf [1], efficiency and effectiveness of the maintenance function will affect the performance of the production system and the capability of the machine to produce quality products. Performance measurement is one of the ways to evaluate the success of an organization. The design and use of performance measurement systems have attracted attention in recent years. Many organizations have redesigned their measurement systems to reflect with their current business [2].

DEA is one of the excellent tools for the benchmarking process. The process is divided into four steps: planning, identification, assessment, and result analysis. In step 1, we have to determine what is the DMU for which a DEA efficiency evaluation would be/which management wants to evaluate for performance, when were activities conducted (for a time-dependent evaluation), who are our comparison partners (for a static condition) and we should ask ourselves why do we have to conduct the exercise.

The next step is to identify the relevant outputs and inputs of the DMU to be evaluated and the DEA model that will be used in the assessment. Specifying inputs and outputs is the most critical aspect of this process. Then, in step 3, DEA is applied to the output and input data

Finally, in step 4, results from Step 3 are analyzed to help management locate and remedy operating inefficiencies. The inefficient units should then be further studied and compared with their efficiency reference-set units in order to ascertain the cause and controllability of the identified inefficiencies.

We can repeat this process by changing the relevant outputs and inputs in Step 2 to observe the affect of a certain input or output. Varying the inputs and outputs used will affect the calculated efficiency scores.

2. DEA Model for Maintenance Performance Measurement

Figure 1 shows the inputs and outputs that can be used to assess maintenance activity performance [3]. The appropriate inputs (cause) are man, machine, money, training, and time, or "3M2T" and the outputs (affect) are production, quality, cost, delivery, safety, morale, and time, or "PQCDSMT". Man, machine, and money are typical inputs for a production system. We added the element of training and time in input because training is an important activity in developing knowledge for employees and time plays a role in minimizing the inputs. Spending a short time in maintenance is better than spending a long time for the same output.

"PQCDSM" is the common measurement index for Total Productive Maintenance [4]. Each index has its own criterion. For example, OEE (Overall Equipment Effectiveness) represent P, the number of complaints represents Q, manufacturing cost represent C, quality rate represented Q, etc. In additional to "PQCDSM", the element of time was included. Time, such as total equipment downtime hours, total maintenance hours etc., is the factors that cannot be ignored in maintenance.

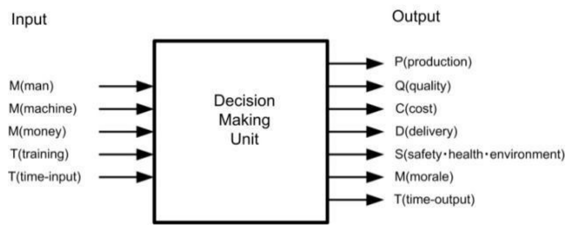

Fig. 1. DEA model for maintenance activity

The idea behind this model is x_1 of manpower who received x_2 hours of training spent x_3 of time performing maintenance activities to x_4 of machine or x_4 of machine that was operated in x_3 of time with x_5 of expenses. These activities then give the result of y_1 of production factor, y_2 of quality factor, y_3 of cost factor, y_4 of delivery factor, y_5 of safety factor, y_6 of morale and y_7 of time factor.

Assuming that there are n DMUs for above model, each with m (m=1,2,...,5)inputs and s (s=1,2,..,7) outputs, the relative efficiency score of a target DMU$_o$, $\theta_o$is obtained by solving the following model proposed by Charnes et al. [5].

$$Max\ \theta_o = \frac{u_1y_{1o} + u_2y_{2o} + ... + u_sy_{so}}{v_1x_{1o} + v_2x_{2o} + ... + v_mx_{mo}} = \frac{\sum_{r=1}^{s} u_r y_{ro}}{\sum_{i=1}^{m} v_i x_{io}} \quad (1)$$

Subject to:

DMU$_1$

$$\frac{u_1y_{11} + u_2y_{21} + ... + u_sy_{s1}}{v_1x_{11} + v_2x_{21} + ... + v_mx_{m1}} = \frac{\sum_{r=1}^{s} u_r y_{r1}}{\sum_{i=1}^{m} v_i x_{i1}} \le 1$$

DMU$_2$

$$\frac{u_1y_{12} + u_2y_{22} + ... + u_sy_{s2}}{v_1x_{12} + v_2x_{22} + ... + v_mx_{m2}} = \frac{\sum_{r=1}^{s} u_r y_{r2}}{\sum_{i=1}^{m} v_i x_{i2}} \le 1$$

…

…

DMU$_o$

$$\frac{u_1y_{1o} + u_2y_{2o} + ... + u_sy_{so}}{v_1x_{1o} + v_2x_{2o} + ... + v_mx_{mo}} = \frac{\sum_{r=1}^{s} u_r y_{ro}}{\sum_{i=1}^{m} v_i x_{io}} \le 1$$

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DMU_j

$$\frac{u_1y_{1n}+u_2y_{2n}+...+u_sy_{sn}}{v_1x_{1n}+v_2x_{2n}+...+v_mx_{mn}} = \frac{\sum_{r=1}^{s} u_r y_{rn}}{\sum_{i=1}^{m} v_i x_{in}} \leq 1 \quad (j=1,2,..,n)$$

$$u_1,u_2,...,u_s \geq 0 \text{ and } v_1,v_2,...,v_m \geq 0$$

where:

j : number of DMU being compared in the DEA analysis
DMU_j : DMU number j
DMU_0: target DMU
y_{rj} : amount of output r used by DMU_j
x_{ij} : amount of input i used by DMU_j
i : number of inputs used by the DMU
r : number of outputs generated by the DMU
u_r : weight assigned by DEA to output r
v_i : weight assigned by DEA to input i

The fractional program shown as *(1)* can be converted to a linear program as shown in *(2)*

$$max\ \theta = \sum_{r=1}^{s} u_r y_{ro} \qquad (2)$$

subject to

$$\sum_{i=1}^{m} v_i x_{io} = 1$$

$$\sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} \leq 0 \ , \ j=1,2,...,n$$

$$u_r \geq 0 \ , \ r=1,2,...,s$$

$$v_i \geq 0 \ , \ i=1,2,...,m$$

3. Maintenance Performance of Malaysia's Automotive Sector: A Case Study

As a case study, we measured a company's maintenance activities performance. The company is a leading automobile manufacturer in Malaysia and started the operations in the early 1990s. The company mainly produces small, compact and low cost cars. The Maintenance Department is responsible for all the equipments in the company including inspection, testing, servicing, and repair of equipment in all sections of the company. For this study, the data was collected from the Maintenance Department and divided into four quarters of a physical year as shown in Table 1.

The company is still at an early stage in implementing TPM within their organization. For this reason, the definition of their performance index is quite different from what was defined by TPM. Therefore, only a part of the model proposed by Fig. 1 can be applied. The usage of different input and output in the assessment will lead to a different result. To further provide validity to the study, the assessment was conducted in two trials.

Table 1. Case study input and output data

	x_1	x_2	x_3	x_4	y_1	y_2	y_3	y_4
Q_1	174	4.28	20	1047	4.59	1	8.1	74.26
Q_2	174	4.62	15	1045	11.38	3	10.2	72.75
Q_3	184	5.13	15	1054	2.38	1	9.2	75.25

Q_4	183	4.95	15	1048	1.46	0	7.8	82.24

For the first trial, four input categories were used: Man, Money, Training and Time. Details for input were:

x_1 : Total no. of technicians
x_2 : Preventive maintenance cost(million)
x_3 : Training per technician (hours)
x_4 : Operating Time (hours)

Number of machines was not included in the input because there were no changes in number of machines during the period when the data was collected.

For output, four categories were used: Cost, Safety, Time, and Production. Details for output were:

y_1 : Total breakdown and unplanned maintenance cost (million)
y_2 : No.of accident
y_3 : Total breakdown hours
y_4 : OEE

The ideal system is a system that results in maximum the output by using the minimum input. From Table 1, we can see that the inputs show a similarity; a lower value is the better. However, for the output, the tendency of the values is mixed. It would be better to attain a greater value for OEE and a lower value for cost(y_1), number of accidents (y_2) and total breakdown hours (y_3). Therefore, we have to convert these values into a "maximize-oriented" output.

For the number of accidents (y_2), the ideal situation is to never have an accident. Therefore, we gave full marks (100 marks) for this situation. Since the worst case for accident is 3 cases, we divided 100 by 4, which gave the 3 accident 25 marks, 1 case 75 mark, and 0 accidents as 100 marks. Forcost(y_1) and total breakdown hours (y_3), we reversed the value in Table 1 by divided it by 1 and taking the percentages. The "new" values are shown in Table 2.

Table 2. "New" value

	x_1	x_2	x_3	x_4	y_1	y_2	y_3	y_4
Q_1	174	4.28	20	1047	21.79	75	12.35	74.26
Q_2	174	4.62	15	1045	8.79	25	9.8	72.75
Q_3	184	5.13	15	1054	42.02	75	10.87	75.25
Q_4	183	4.95	15	1048	68.5	100	12.8	82.24

In the second trial, we omitted OEE (y_4) from Table 1 and the assessment was conducted using total no. of technicians (x_1), preventive maintenance cost (x_2), training per technician (x_3) and operating time (x_4) as the inputs, and total breakdown and unplanned maintenance cost (y_1), number of accidents (y_2) and total breakdown hours (y_3) as the outputs.

Figure 2 compared the efficiency obtained from the assessment during first trial and second trial using CCR Model of DEA. The figure indicates the affect of OEE in the case study organization. Without OEE as the output in second trial, the efficiency of Q_2 became less than Q_3 as shown in Fig.2.

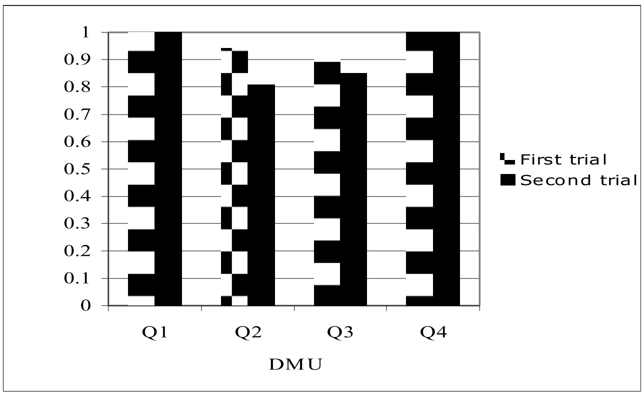

Fig. 2. DEA model for maintenance activity

4. Discussion and conclusion

Measurement in an automobile assembly company using a part of the proposed model was conducted. This assessment was done by using DEA CCR Model for the evaluation. The assessment was performed in two trials to demonstrate the importance of identifying the inputs and outputs as stated in phase two of the process flow.

The value of output must be reverse to make it as “maximize-oriented” values because if we use the original data as per Table 1, the results indicates Q_2 as the most efficiency period due to a very large value for y_1 in Q_2. However, in a real situation, spending significant amounts of money for breakdown and unplanned maintenance is not a good action. It shows that the preventive maintenance is not functioning very well.

The results of this study highlight the importance of the inputs and outputs used in determining relative efficiency. The absence of certain input or output will affect the effectiveness of an activity, whether getting better or worse. Therefore, selection of input and output is another important decision that should aware and taken into accounts. This might be the first thing that should be decided before proceed with the rest of the tasks.

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