A Framework for Measuring The Effect of Changeover Time To Overall Equipment Effectiveness

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ABSTRACT

Single Minutes of Exchange Die (SMED), developed by Shigeo Shingo is an approach to improve changeover of die by reduction its setup time. Longer setup time will lead to shorter Availability in Overall Equipment Effectiveness (OEE), thus will give effect to the actual time of production. For this reason, a study need to be conducted to measure how the performance of setup or changeover process effect the Availability in OEE. This paper propose a framework on how to measure the effect of changeover time to OEE by using Data Envelopment Analysis (DEA). The study benchmark Single Minutes of Exchange Die process in the same production line dynamically. The manpower and the external setup time are the main inputs in this measuring process where the main output is the Availability of OEE. This framework can be used to determine the efficiency of converting internal setup time to external setup time. An efficient converting process from internal setup time to external setup time will give a good effect to the Availability and thus contribute to the longer production time.

Keyword: Single Minutes of Exchange Die, Overall Equipment Effectiveness, Data Envelopment Analysis

1. Introduction

Due to complex design of the product and high competition among manufacturers, manufacturing in today's world rely more on the usage of the machine. Machine need to be set-up and maintained. Time used for machine set-up will affect actual future production. If we spend more time in setting up the machine, it will cause the time used for the production will be shorter. This factor also applies to the exchange of die in a production line. A longer time used to exchange the die will cause the time to begin the production will be delayed.Set-up time can be considered as a waste in a production line because it does not contribute directly to production output. Thus, how to shorten the time to exchange the die became a research topic for several companies for last few decades.

One of the most popular approach that been applied widely is Single Minutes of Exchange Die (SMED). SMED was initiated in early 1950s by Shigeo Shingo, a Japanese Industry Engineer to utilized to reduce setup time and provide quick equipment changeover and rapid die exchange [1]. The objective of SMED is to reduce setup time to a single digit minute or less than 10 minutes. This approach allows manufacturers to switch from one product to another rapidly and produce products in small batches with short lead time.

Machine downtime due to set-up time will reduce the actual production running time or the Availability in Overall Equipment Effectiveness. The OEE is a key performance indicator (KPI) that provides the overall performance of a single piece of machinery, or for an entire factory. Availability(A) is one of OEE's three measurable components besides Performance Rate (PR), and Quality Rate (QR) [2]. Having low OEE's value means that the machine is not performed as it should be. Therefore, it is a necessary to measure the effect of die's exchange time to overall equipment effectiveness.

This paper propose a framework to measure the effect of die's exchange time to the Availability in OEE dynamically. We use Data Envelopment Analysis (DEA) to benchmark the SMED activities to observe the performance's trend in each predetermined time zone. In this research, SMED activities are considered as DMU or Decision Making Unit, the entity who participate in a decision process. In this case, SMED activities are the one that play the important role in deciding the performance of the machines in the company. The most important in this exercise is to determine what are input and output of the DMU because these input and output will reflect what we are looking for.

2. Literature Review

2.1 Single Minutes of Exchange Die (SMED)

SMED suggests an easy approach to improve changeover operations significantly. The objective can be achieved by reducing the setup time, that is, the time elapsed between producing the last good product of the first lot and the time of producing the first good product of the next lot [3].

According to Shigeo (1989), setup operations consists of two fundamentally different types: Internal setup and External setup. Internal setup is a process that can be performed only when a machine is stopped such as mounting or removing dies while External setup is a process that can be conducted while a machine is in operation such as such as transporting old dies to storage or conveying new dies to the machine.[4]

Shigeo (1989) [4]stated that setup time is comprised of following four functions;
1. Preparation of material, dies, jigs, and fixtures that take 30 percents of setup time,
2. Clamping and removing dies and tools that take 5 percents,
3. Centering and determining dimensions of tooling that takes 15 percents, and finally,
4. Trial and adjustment that takes 50 percents from overall setup time.

There are four conceptual stages in SMED; preliminary stage, separating internal and external setup stage, converting internal to external setup stage, and finally streamlining all aspects of the setup operation stage. Stage two is the most crucial stage in the implementation of SMED because we only can reduce set-up time if most of the necessary tasks in exchanging the die are performed while machine is running.

Stage one is a preliminary stage, where there is no distinction is made between internal and external setup. Many necessary tasks that could be performed as external setup are executed while the machine is down. Stage two is to identify which set-up operation must be performed while the machine is shut down(internal setup) and which can be performed when the machine is running(external setup). In stage three, we analyze the current setup operation to determine whether any of the activities conducted as internal setup can be converted to external setup. If we can convert more internal set-up time to external set-up time, our setup time will be shorter. Finally, stage four is the stage where we examine both internal and external setup operations for additional opportunities for improvement.

SMED can give the benefits such as; machine operating rates will be increased by shortening setup times, small lot production significantly reduces finished goods inventories and the buildup of stocks between processes, increased production flexibility to respond to rapidly changes in model and delivery time requirements, and finally, eliminate time spent in waiting for processing of one lot to be completed before another lot can be processed[4].

As SMED had been developed 60 years ago, many researchers attempt to make improvements to the SMED. For example, Almomani et al (2013) incorporates Multiple Criteria Decision-Making Techniques (MCDM) techniques to SMED's stage three. The MCDM techniques used in this work are Analytical Hierarchal Process (AHP), Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) and Preference Selection Index (PSI). In addition to the reduction in the setup time, the proposed approach takes into consideration various factors, that govern the setup selection technology; including: cost, energy, facility layout, safety, life, quality and maintenance[3].

Karasu et al (2014) incorporated Taguchi design of experiment into SMED methodology to achieve the parameter set that provides the quality product with fewer trials to start the mass production[5]. Moxham and Greatbanks (2001) suggested that the effective implementation of SMED necessitates a number of fundamental requirements.Therefore, they proposed prerequisite requirements for successful SMED application, defined as SMED-ZERO. According to Moxham and Greatbanks, the SMED-ZERO attributes must be in place before the traditional SMED techniques can be applied successfully[6].

2.2 Overall Equipment Effectiveness (OEE)

OEE is a key measurement in indicating how many products the equipment is turning out, how much of the time the equipment is actually working, and what percentage of the output is the good product. Since OEE reflects these three important elements, it is an important indicator of equipment health. The three elements that account in calculating OEE are:

1. Performance Rate: a comparison of the actual output with what the machine should be producing at the same time.
2. Availability: a comparison of the potential operating time and the time in which the machine is actually making products.
3. Quality Rate: a comparison of the number of products made and the number of products that meet the customer's specifications.

Figure 1 provides a visual description of how OEE is derived from the three elements.

The ideal for totally effective equipment is that it could run all the time, could maintain its maximum or standard speed all the time, and never produces defective products. However, equipment cannot run continuously, cannot maintain standard speed without problems, and equipment make defects. These problems are familiar forms of waste that can reduce equipment's effectiveness. The conditions that cause these equipment problems are called "equipment-related losses" [7]. Equipment-related losses that are important for OEE are linked to the three elements measured in OEE: Availability, Performance Rate, and Quality Rate. Beside breakdown loss and cutting tool loss, set-up time loss also a major elements in reducing the Availability.

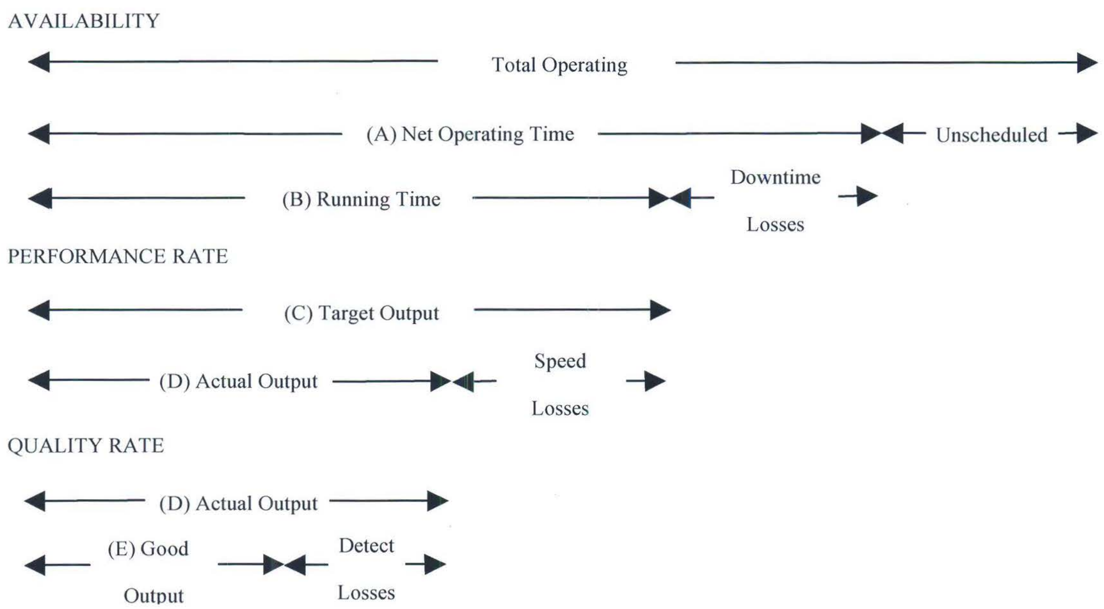

Figure 1: The OEE Elements
(Source: The Productivity Development Team,2004)

$$OEE = \underset{\text{(Availability)}}{B/A} \times \underset{\text{(Performance Rate)}}{D/C} \times \underset{\text{(Quality Rate)}}{E/D} \times 100\%$$

2.3 Data Envelopment Analysis (DEA)

DEA is a technique of analyzing the efficiency of the organization using linear Making unit). DMU refer to the collection of private firms, non-profit organizations, departments, administrative units, and groups with the same (or similar) goals, functions, standards and market segments. A DMU is regarded as the entity responsible for converting inputs into outputs and DEA measures the efficiency of the conversion process.

Hence, DEA can be used to evaluate and improve the performance of manufacturing and service operations. DMU may include banks, department stores and supermarkets, and extend to car makers, hospitals, schools, public libraries and so forth[8]. Rather than the conventional one input to one output, DEA evaluates multiple inputs and multiple output systems on the basis of what is most excellent in the efficiency value. The DMU is most efficient if the efficiency obtains a score of one and is inefficient if the score is less than one. Therefore, for every DEA calculation, the objective is to maximize the value of the efficiency.

Assuming that there are *n* DMUs for the model, each with *m* inputs and *s* outputs, the relative efficiency score of a target DMU_o, θ_o is obtained by solving the following model proposed by Charnes et al. [9].

$$Max \quad \theta_o = \frac{u_1 y_{1o} + u_2 y_{2o} + \ldots + u_s y_{so}}{v_1 x_{1o} + v_2 x_{2o} + \ldots + v_m x_{mo}} = \frac{\sum_{r=1}^{s} u_r y_{ro}}{\sum_{i=1}^{m} v_i x_{io}} \tag{1}$$

Subject to:

$$v_i \geq 0 \;, \quad i = 1,2,\ldots,m$$

where:

y_{ro} : amount of output *r* used by DMU_o

x_{io} : amount of input *i* used by DMU_o

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*

DMU_0 is the target DMU and this calculation will be repeated by changing the target DMU.

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

$$max \;\; \theta = \sum_{r=1}^{s} u_r y_{ro} \tag{2}$$

subject to

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

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

$$u_r \geq 0 \quad , \quad r = 1,2,\ldots,s$$

DMU is most efficient if the efficiency θ^* = 1, otherwise DMU is considered inefficient.

3. A Framework for Measuring The Effect of Changeover Time To Overall Equipment Effectiveness

First thing that need to be considered is to determine what are the input and output that involved in this process. For this framework, as shown in Figure 2, we adopted two-stage DEA that originally proposed by Y.Li et al[10]. The outputs from the first stage become the inputs to the second stage with additional extra input. The measurement in-between the two stages are called intermediate measures.

We use total working hour, no.of worker involved in the process and external set-up time consumed in the process as the input and for the output, we use internal set-up time. The idea behind this model is x_1 of total working hour of x_2 workers and x_3 of external set-up time that give the result of z_1 of internal set-up time. The stage 1 measures the efficiency of converting internal set-up to external set-up. Short or not the external set-up time depends entirely on the internal set-up time. On the other hand, the internal set-up time depends on how many workers involved in the process and how long they work on it.

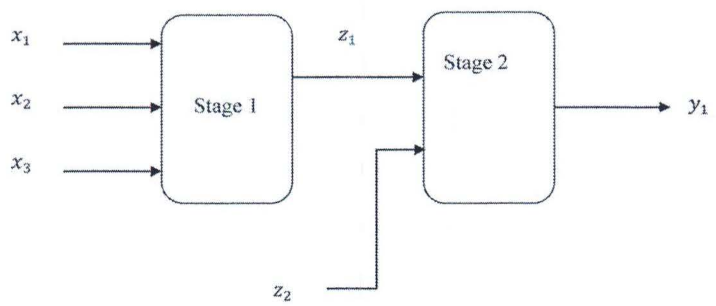

Figure 2: Framework model for measurement

Since downtime losses reduce the Availability of OEE, we use downtime losses time as the input for the second stage. In this case, we define downtime losses as the combination of internal set-up time and breakdown time that include cutting time. We use internal set-up time z_1 that came as output from stage 1 and we add breakdown time z_2 as the input for stage 2. For the output, we use the value for the Availability of OEE.

The next step for this exercise is to determine what our DMUs are. If we want to benchmark the SMED process in the same production line dynamically, we need to compare the same process in the same production line time by time. For example, we collect the data as described in the model in Figure 2 every months and data for a month can be considered as one DMU. Therefore, we will have 12 DMUs that can be used to benchmark between each others. For sure, the most recent months will appear as the most efficient DMU but it is important to know that how the Availability changed from the beginning of the process until now. We also can notice that it is set-up time that effect the Availability or other factors.

4. Conclusion

The most crucial part in this exercise is to collect or measure accurate time for both internal and external set-up.Without accurate data, this exercise is meanless because the result obtained is not reflect the real situation. Therefore, companies need to validate either their existing data are accurate and sufficient enough for the exercise. This is to ensure that they will get the correct answer to their problems. Otherwise, they will plan a management strategy based on misinformation.

Theoretically, we believe that this framework can help industries to determine either their SMED process is doing well or not giving any significant change from the day they implemented SMED until today. Put more workers or spend more time to the process might reduce the setup time and increase the Availability but at the same time will increase the operation costs.Thus, it is necessary to know the effect of the process to the entire production. As our future works, we would like to validate this framework using the actual data from one of the metal stamping company in Malaysia.

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