A CASE STUDY: SMED CONTRIBUTOR USING SHAPLEY VALUE

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ABSTRACT

Single Minute Exchange Die (SMED) is one of lean tools to reduce setup time. Throughout the application of SMED, the effectiveness of this tool is unknown because there is no method to calculate its performance measurement. As long as time reduction takes place, the implementation of SMED achieves its target and goal. However, throughout the implementation of SMED most companies pay more attention on reducing time in their activity, but do not take into consideration the performance during the time reduction process. Therefore, the Shapley value method is applied to identify the performance of SMED during the time reduction process occur. In this method, a game theory concept is used to calculate the testing factors that need to be measured: time, machines, activities etc. where testing factors can represent as player and contributor. From the calculation, a fair coalition among testing factors can be identified and elimination of the unnecessary activities during the time reduction process is measured.

KEYWORDS*: Single minute exchange of die (SMED); performance measurement; Shapley value*

1.0 INTRODUCTION

Shorter time for changing die process needed as highly demand by customer that also require high cost. Due to that, high cost needed as of high operation cost, thus resulting in lower gaining a profit. Earlier, the price of products depends on the cost of manufacturing and profit margins, but now most product price have fixed while benefit aimed at reduction manufacturing cost. In addition,

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shorter time of changeover leads to the short time of the production process. Single minute exchange of die (SMED) was developed to improve machine tool setups, but principles were implemented to several of the production process (McIntosh et al. 2010). This method is used to overcome the rapidly changing of a mould or die, which depends on the number of processes, involve producing one complete part. Since changing die occurs during machine shut down, thus causing losses to the company.

In this paper, the Shapley value method identifies the fair distribution of the contributions obtained between the activities in production line. Extended knowledge from Mansor, M.A., (2016) Shapley value can identify the coalition between SMED contributors - that is machine, and can determine which machines contribute the most during the production process. By using Shapley's method, each activity will considered as the players while each machine involved as the contributors. The combinations of the contributors and players will create a number of permutations. The notion of permutation relates to the act of arranging the players and contributors into some sequence or rearranging (reordering) its elements will allocate the coalition of marginal contribution of each player. The coalition between the two factors will be evaluated.

2.0 LITERATURE REVIEW

2.1 Single Minute Exchange of Die (SMED)

Single Minute Exchange of Die (SMED) is one of the lean tools to reduce changeover time during internal setup which cause flexibility and efficiency in the production process. This tool has widely implemented in thr automotive sector as well as in plastic industry. This method proposed by Shingo (1958) as waste elimination through the reduction of unnecessary activities during yjr setup process and time reduction for tool change in setup time. All activities in SMED setup operations can be divided into two categories that is internal setup and external setup. Internal setup activities which are performed while the machine is stopped and therefore must be minimized because it slow down the production, and external setup activities that are performed while the machine is running (Shingo & Andrew, 1989). The authors also stated that setup time is comprised of following four functions;

- Preparation of material, dies, jigs, and fixtures that take 30% of setup time,
- Clamping and removing dies and tools that take 5%,
- Centering and determining the dimensions of tooling that takes 15%, and
- Trial and adjustment that takes 50% from the overall setup time.

There are four conceptual stages in SMED, which are preliminary stage, separating internal and external setup stage, converting internal to THE external setup stage, and finally streamlining all aspects of the setup operation stage. Among these stages, separating internal setup and external setup is most critical stage to carry out since the machine is still necessary for running tasks in exchanging the die.

Stage one in SMED is the preliminary stage, where the aim is to have an overall image for all setup activities included in the changeover process. At this stage, current setup data will be collected by using a standard operation setup checklist and to fulfill their corresponding required resources. This can be done through the interviews with the person in-charge of machines, followed by time and motion study using video tape to determine the standard time for each operation. 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). All activities occur during the process must take note because detail information needed for the next stages which converting internal setup activities to external setup activities. In this stage, the elimination of unnecessary activity or convert the existing internal activities to be done as external activities when the machine is shut down. Final stage, streamlining all aspects of the setup operation whether the converting activities achieve SMED core goal which is to reduce changeover time.

For two decades, modifying the conventional SMED has received an extensive attention, and there are always arguments about the expected improvement obtained by improving activities within each implementation stage in order to focus the efforts to the implementation phase that produces the maximum improvement (Alves & Tenera, 2009; Kumaresan & Saman, 2011; Melton, 2005). However, the application of SMED will be viewed if the performance measurement has taken into account in identifying its effectiveness.

2.2 Shapley Value

The Shapley value, proposed by Lloyd Shapley (1953) is a Game Theory concept used to determine the fair distribution of the profit obtained by collaboration among players. It also can be used to determine the contribution of each player in a coalition game to achieve the goal. A coalition game is where groups of players (coalitions) compete due to cooperative behavior between their members. For example, in a soccer game, eleven players are playing together as a team to win the game. Each player contributes their skills to the team and the team with the higher value of a combination of skills will win the game. Hence, the game is a competition between coalitions of players, rather than between individuals.

A subject that contributes to the activity represent as the player and the elements that players contribute to the whole activity represent as the contributor. A player's Shapley value contribution gives reflect on how much value the contribution adds to the coalition while a contributor never adds much has a small Shapley value, while the contributor that always makes a significant contribution has a high Shapley value. Assume that there are n players with m contributor and let w be the weight to the contributor. Any subset S of the player set N = (1,…, n) is called a coalition. The record for the coalition S is defined by Equation (1);

$$x_i(S) = \sum_{j \in S} x_{ij} \qquad (i = 1, \ldots., m) \tag{1}$$

where
x_{ij} is the record of player j to the contributor i.

This coalition aims at obtaining the maximal outcome c(S) as shown in Equation (2).

$$c(S) = \sum_{i=1}^{m} w_i \, x_i(S) \tag{2}$$

subject to

$$\sum_{i=1}^{m} w_i = 1 \qquad w_i \geq 0\ (\forall_i)$$

The *c(S)*, with *c*(Ø)=0, defines a characteristic function of the coalition *S*. Thus, we have a game in coalition form with transferable utility, as represented by (*N*, *c*). The Shapley value of the game (*N*, *c*) for the player *k* is the average of its marginal contribution to all possible coalitions as given in Equation (3).

$$\varphi_k(c) = \sum_{all\ S} \gamma_n(S)[c(S) - c(S - \{k\})] \tag{3}$$

With weights of probability to enter into a coalition *S* defined by Equation (4).

$$\gamma_n(S) = \frac{(s-1)!\ (n-s)!}{(n)!} \tag{4}$$

In Equations (3) and (4), *n* is the total number of all the participants, *s* is the number of members in the S^{th} coalition, and *c*(×) is the characteristic function used for estimation of utility for each coalition. If a subset *S*(⊂ *N*) includes player *k*, *k*'s marginal contribution is obtained as *c*(*S*)-*c*(*S*-{*k*}).

2.3 Performance Measurement

The performance measurement is one of important program in Total Quality Management (TQM) where the development, implementation, and operation of performance measurement systems are studied. The implementation of performance measurement should involve in organizing because it stimulates the ideas and strengthen their ideas that will lead to success. For the last two decades, Neely (1999) suggests that the performance measurement is practically advantageous and cost-effective way to measure the performance in production line. Neely states that performance measurement can be analysed based on these three different levels, which are individual performance, the core of performance measurement system and the relationship between performance measurement and its environment. He also concludes that there are four categories that include in individual measurement which are quality, time, cost and flexibility. Time is one of the factors that will affect the performance measurement if company waste more time in changing die during the internal setup time.

3.0 DATA COLLECTION AND ANALYSIS

Data collection of complete changeover process of internal setup activities is summarized in Table 1.2. There are three stamping machines in a production line, namely M_1, M_2, and M_3 for each activities remove die, setting die, parameter setting and quality confirmation stage which represents as A_1, A_2, and A_3 and A_4 respectively. By using the Shapley value method, the coalition between contributor and player can be determined. The time consumed for each activity is represented as t_{mn}. J_m is the total times spent by each contributor or activity. These symbols will be used next.

Table 1.2. Internal setup time in press machine

Player / Contributor	M_1	M_2	M_3	Sum (J_m)
A_1	2.45	2.30	2.58	7.33
A_2	3.40	2.45	2.21	8.06
A_3	1.25	2.01	1.45	4.71
A_4	1.35	2.02	2.16	5.53

From Equation (2), maximum outcome of $c(M_1)$ is given by;

$c(M_1)$=max $t_1w_1 + t_2w_2 + t_3w_3$

subject to:

$w_1 + w_2 + w_3 = 1,$

$w_1, w_2, w_3 \geq 0$

where w is the weight of the contributor. The optimal solution, $c(M_1)$ can be obtained when w_1=1, w_2 =0, and w_3=0. From Table 1.3, all coalition's values for each contributor will be enumerated. For example, the value of coalition $\{M_1,M_2\}$ for contributor A_1 is given as $\frac{t_{11}}{J_1} + \frac{t_{12}}{J_1}$. Coalition $\{M_1,M_3\}$ and $\{M_2,M_3\}$ are calculated by $\frac{t_{11}}{J_1} + \frac{t_{13}}{J_1}$, $\frac{t_{12}}{J_1} + \frac{t_{13}}{J_1}$, respectively.

Table 1.3. Normalized values

Contributor \ Player	M_1	M_2	M_3	*Sum*
A_1	0.3342	0.3138	0.3520	1.0000
A_2	0.4218	0.3040	0.2742	1.0000
A_3	0.2654	0.4268	0.3079	1.0000
A_4	0.2441	0.3653	0.3906	1.0000

The combination of player M_1, M_2, and M_3 created 24 permutations. In permutation $M_1M_2M_3$, player M_1 is the first comer to the coalition, follows by player M_2, and finally player M_3, Thus, the marginal contribution of each player to coalition can be evaluated as below. M_3's marginal contribution is c({M_1,M_2,M_3}) - c({M_1,M_2}) and M_2's marginal contribution is c({M_1,M_2}) - c({M_1}).

Table 1.4. Coalition values

Contributor \ Coalition	M_1, M_2	M_1,M_3	M_2, M_3	*Sum*
A_1	0.6480	0.6862	0.6658	1.0000
A_2	0.7258	0.6960	0.5782	1.0000
A_3	0.6921	0.5732	0.7346	1.0000
A_4	0.6094	0.6347	0.7559	1.0000

Lastly, M_1's marginal contribution can be derived from c({M_1}) - c({Ø})

The same calculation, then was repeated for every permutation. The average of the marginal contribution of the player was respectively taken and this average is described as the Shapley value. Furthermore, each player's Shapley value was divided by the highest value of the Shapley value to obtain a score for each player.

SoB = Shapley value for each player /(the best Shapley value among the players)

Table 1.5. Shapley values

Player / Contributor	M_1	M_2	M_3
Shapley value	0.3164	0.3525	0.3312
SoB	0.8976	1	0.9396
SoB in (%)	89.76	100	93.96

4.0 CONCLUSION

At the conclusion, by using the Shapley value method, the coalition among three machines can be identified. Machine M_2 contributes the most because achieve 100% in Scale of Balance. Both machines M_1 and M_3 need for some adjustment or reform a new schedule for an external setup time in order to have all the machines working at their maximum. Based on actual data collection, the model suitable to be practiced by the company that has been implemented SMED and want to identify how the effectiveness of SMED throughout its implementation. The company can also investigate how decision-making takes place along the implementation are worth or improvement occurs during process gaining profit for their company. In order to make improvement, data analysis needed because it will lead to good decisions. Nevertheless, incorrect data will lead to a wrong decision and this decision could give a bad impact for the company.

ACKNOWLEDGMENT

This research was fully supported by the Ministry of Higher Education (MOHE) of Malaysia under the project no. RDU151310 of the Research Acculturation Collaborative Effort (RACE) research grant.

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