A CASE STUDY OF PERFORMANCE MEASUREMENT METHOD FOR SINGLE MINUTE EXCHANGE OF DIE (SMED) IN METAL STAMPING INDUSTRY

SUAIDAH SYAZWANI BT SULAIMAN

MASTER OF SCIENCE

UNIVERSITI MALAYSIA PAHANG

UNIVERSITI MALAYSIA PAHANG

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Position : SENIOR LECTURER

____

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ID Number : MMF16001

Date :

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SUAIDAH SYAZWANI BT SULAIMAN

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ABSTRAK

Single Minute Exchange of Die (SMED) adalah satu kaedah yang diperkenalkan oleh Shingo pada awal tahun 1950-an untuk mengurangkan masa persediaan dan menyediakan pertukaran peralatan dan pertukaran acuan dengan cepat. Sepanjang 20 tahun lalu, revolusi teknik SMED membantu bidang pembuatan terutamanya dalam pengeluaran untuk meminimumkan masa bagi proses pertukaran acuan. Sepanjang sedekad yang lalu, keperluan masa persediaan yang lebih pendek dalam pertukaran acuan telah meningkat berikutan permintaan pasaran dalam semua jenis industri. Pengurangan masa yang terhasil daripada penukaran persediaan dalaman kepada masa persediaan luaran di SMED membolehkan masa pengeluaran dapat dipendekkan. Ini menjadikan pengurangan masa sebagai titik penting untuk meningkatkan prestasi dalam barisan pengeluaran. Walau bagaimanapun, sebahagian besar syarikat yang melaksanakan SMED memberi perhatian lebih terhadap mengurangkan masa dalam aktiviti mereka, tetapi tidak mengambil kira prestasi sepanjang proses pengurangan masa berlaku. Semasa proses pengurangan masa, tanpa mengetahui, input yang tidak perlu seperti kos, tenaga kerja dan masa boleh diambil untuk mendapatkan masa yang disasarkan yang perlu dikurangkan. Selain itu, ketidakseimbangan input yang digunakan dari semasa ke semasa akan menjejaskan prestasi dan keberkesanan SMED. Terdapat tiga objektif kajian ini iaitu membina model untuk mengukur prestasi SMED sepanjang pelaksanaannya di syarikat pembuatan. Kemudian, untuk mengukur taburan adil di antara parameter terpilih menggunakan Nilai Shapley dan akhirnya untuk mengukur prestasi trend aktiviti dan masa menggunakan Analisis Pemindahan Gabungan (MCA) dan Analisa Gabungan Pertukaran Transpor (T-MCA). Kajian ini bermula dengan pengumpulan data mengenai aktiviti yang terlibat dalam SMED untuk pengeluaran tekapan logam. Penemuan parameter yang memenuhi skop untuk pengukuran keberkesanan adalah bahagian yang paling sukar. Dalam kajian ini, data masa setiap aktiviti disahkan menggunakan model DEA yang mengukur kecekapan SMED manakala Nilai Shapley akan menilai pengedaran yang saksama di kalangan pemain terpilih. Keputusan dari setiap kaedah akan membandingkan parameter dan DMU yang manakah menunjukkan nilai terbaik. Hasil kajian ini ialah input dan output yang sesuai / berkaitan untuk model DEA telah dicadangkan untuk mengukur keberkesanan SMED proses petukaran dalam barisan pengeluaran. Aktiviti yang terlibat dalam proses pertukaran dan masa yang digunakan untuk aktiviti dikenal pasti sebagai parameter dalam menentukan sumbangan setiap aktiviti di SMED. Parameter yang sama digunakan untuk penilaian dinamik yang memberi tumpuan kepada trend dalam siri masa bagi setiap tempoh dan siri masa aktiviti keseluruhan masing-masing. Hasil keputusan daripada teknik kombinasi ini boleh digunakan untuk mengukur betapa baiknya peningkatan yang dilakukan dengan memahami sumbangan setiap kecekapan dalam proses perubahan. Kaedah gabungan ini digunakan kerana model DEA hanya dapat mengukur kecekapan SMED, manakala Nilai Shapley akan mengukur sumbangan setiap keberkesanan sepanjang pelaksanaannya.

ABSTRACT

Single Minute Exchange of Die (SMED) is a method introduced by Shingo in early 1950s to reduce the setup time and provide quick equipment changeover and rapid die exchange. For 20 years, the revolution of SMED techniques helps the manufacturing field especially in production to minimize the changeover time process. During the last decade, the need of shorter setup time in changing die has increased due to market demand in all types of industries. The time reduction resulting from the conversion of internal setup to external setup time in SMED allows production time can be shortened. This makes the time reduction as a key point to improve performance in production line. However, most of the companies that are implementing the SMED pay more attention on reducing time in their activity, but do not take into consideration the performance during the entire time reduction process. During the time reduction process, without knowing, the unnecessary input such as cost, manpower and time might be consumed to obtain the targeted time that need to be reduced. Apart of that, the imbalance of inputs consumed from time to time will affect the performance and effectiveness of SMED. There are three objectives of this research which is to develop a model to measure the performance of SMED along the implementation of it in the manufacturing company. Then, to measure the fair distribution among selected parameters using Shapley Value and finally is to measure the performance of trends of activity and time using Moving Coalition Analysis (MCA) and Transpose-Moving Coalition Analysis (T-MCA). This research begin with data collection regarding activities involved in SMED for metal stamping production line. Findings the parameter that meet the scope for effectiveness measurement is most difficult part. In this research, data time of each activities is validate using DEA model which to measure SMED efficiency while Shapley Value will evaluate the fair distribution among selected players. The results from each method will be compared on which parameters and DMUs shows the best value. As a result, a suitable/relevant inputs and outputs for DEA model have been proposed to measure the SMED's effectiveness of the conversion process in stamping production line. The activity involved in changeover process and the time consumed for activities are identified as parameter in determining the contribution of each activity in SMED. The same parameters is used for dynamic evaluation which focus on the trends in the time series for each periods and time series of overall activity respectively. The result from combination measurement technique can be used to measure how excellent the improvement done by understand the contribution of each efficiency in the changeover process. This combination method is used since the DEA model only can measure the efficiency of SMED, but Shapley Value will measure the contribution of each effectiveness throughout its implementation.

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LIST OF SYMBOLS

$\emptyset$	Unique Value Function
θ	Efficiency
γ	Weights of Probability
φ	Marginal Contribution

LIST OF ABBREVIATIONS

DEA	Data Envelopment Analysis
DMU	Decision Making Unit
MCA	Moving Coalition Analysis
OEE	Overall Equipment Effectiveness
QAQC	Quality Assurance and Quality Control
SMED	Single Minute Exchange of Die
SoB	Scale of Balance
T-MCA	Transpose Moving Coalition Analysis

CHAPTER 1

INTRODUCTION

1.1 Introduction

Single Minute Exchange of Die (SMED) is a method introduced by Shigeo Shingo in early 1950s for Japanese Industry to reduce the setup time and provide quick equipment changeover and rapid die exchange (Desai and Warkhedkar, 2011). The word single minute come from the goal of reducing changeover times to the “single” digit which from one to ten minutes. Throughout 20 years, the revolution of SMED techniques helps the manufacturing field especially in production to minimize the changeover time process. A successful implementation of SMED gives smaller lot sizes, lower the manufacturing cost, lower inventory levels and standardized change over processes to improve consistency and quality (Shingo, 1985). This can help the company to immediate respond on their customer demands since the machine downtime is reduced during changeover process which allow the manufacturing system to increase.

SMED is one of important lean tools to reduce waste and improve flexibility in manufacturing processes which allow the lot size reduction and manufacturing flow improvements. The implementation of SMED also reduces the non-productive time by streamlining and standardizing the operations for exchange tools, using simple techniques and easy applications. Alves and Tenera (2009) concluded that the SMED methodology can be combined with other classic tools, providing very positive results for companies such as chart analysis and statistical analysis that allowed the identification and separation of different groups for analysis, and added value of traditional SMED methodology. This will build up the production level if time been reduce in transporting the die to production line. The application of SMED methodologies is an effective way to analyze, improve and reduce existing processes used to change over manufacturing equipment. (Michels, 2007). Due to that, SMED reduce small lot production can reduce finished goods inventories, increased production flexibility in changing model and delivery time requirement, and eliminate the time waiting for each lot to be complete their process.

Although the SMED technique's impact and contribution to reduce or eliminate setup and changeover time loss is undeniable, but there is no method either calculation shows the improvements was the good decisions. For many years, 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). Modifying the equipment is the most common way to convert setup activities from internal to external to reduce setup time but and there is no performance measurement during the time reduction process take place along the improvement was done. In order to identify the effectiveness implementation of SMED, a new model is proposed to represent the performance along time reduction process are worth with the improvements in each implementation phase.

The previous works proved that SMED is capable to improves setup activities in various industries but the performance along improvement in each implementation of SMED was not measured. Moxham and Greatbanks (2001) claimed that the adoption of setup measurement in SMED enables companies to understand where they currently stand in setting up a process. The measurement indicator of setup performance is vital for measuring and monitoring the improvement of the setup process. Based on the wide applications of SMED, setup time reduction is the common measurement indicator of setup performance improvement. (Ulutas, 2011). Setup or changeover happens when certain tasks need to be carried out at the end of a production run for a particular product or part while the machine is stopped before the next production. Examples of such activities are removing or attaching dies, changing parameters, changing material specifications, etc. Another form of setup or changeover is known as external setup which refers to tasks carried out while the machine is still running and does not contribute to Overall Equipment Effectiveness (OEE) loss, for example preparing a die to be used for the next run. (Rubrich and Watson, 2004; Patel et al., 2001; Trovinger and Bohn, 2005).

Indicators used to measure setup improvement through SMED including process capability analysis, activities in changeover, setup cost, and distance travelled by operators during the changeover process. For example, Cakmakci (2009) used the process capability analysis to quantify SMED capability in one process to indicate process variability and process deviation. However, none of the works on setup reduction focused on improving setup activities from the perspective of process effectiveness. The existence of effectiveness measurement techniques can differentiate the issues, problems, and potentials for improvement and development during the setup process in a short time frame. Therefore, a setup reduction approach that embraces performance measurement in terms of effectiveness must be developed to improve the setup process performance.

1.2 Research Question

1. What are the inputs and outputs that need to be concerned in measuring SMED performance?
2. What model is used to measure the performance of SMED that implement in the manufacturing company?
3. How each activity contribute on the performance of SMED in production line?
4. How to measure SMED performance?

1.3 Problem Statement

During the last decade, the need of shorter setup time in changing die has increased due to market demand in all types of industries. SMED is a method to reduce setup time and provide quick changeover and rapid die exchange. The time reduction resulting from the conversion of internal setup to external setup time in SMED allows production time can be shortened. This makes the time reduction as a key point to improve performance in production line.

However, most of the companies that are implementing the SMED pay more attention on reducing time in their activity, but do not take into consideration the performance during the entire time reduction process. During the time reduction process, without knowing, the unnecessary input such as cost, manpower and time might be consumed to obtain the targeted time that need to be reduced. Apart of that, the imbalance of inputs consumed from time to time will affect the performance and effectiveness of SMED.

Therefore, the performance of SMED needs to be measured to know the activities performed are worth with the input consumed. This can be done by proposing a measurement model that can interpret and clarifying all stages in SMED such as preliminary stage, separating internal and external setup stage, converting internal to the external setup stage, and streamlining all setup operations stage. The model will evaluate each activity in the process to determine the efficiency of SMED, thus lead to understand, manage right decision and improvement that company can make.

1.4 Objective

The objectives of this research are:

1. To determine the performance of SMED along the implementation in the manufacturing company by using the modified DEA model.
2. To determine the fair distribution among selected parameters using Shapley Value.
3. To determine the performance of trends of activity and time using Moving Coalition Analysis (MCA) and Transpose-Moving Coalition Analysis (T-MCA).

1.5 Scope of Dissertation

The scope of the dissertation is summarized as follows:

1. This research focuses on determining the efficiency of SMED application related to selected input which is time consume, manpower, internal activities and external activities.
2. This research used the traditional Data Envelopment Analysis (DEA) which is the CCR model introduced by Charnes, Cooper and Rhodes (1978) to identify the performance of SMED that implement in production line.
3. This research used Sharpley Value to identify fair contribution among selected factor during changeover process in their production line.

1.6 Research Approach

In this research, the performances of Single Minute Exchange of Die (SMED) undergo calculation because all the activity in changeover will be measured in order to identify the effectiveness implementation of SMED. In order to achieve SMED goal, the inputs collected from the operating system, includes changing over time, manpower involves, activity in changeover, costing involve and schedule of the changeover will be studying to get more understanding the processes involve in the production floor.

A model is used to measure the performance of SMED whether the improvement made is worth with the time consumed along the implementation. A game theory concept by Lloyd Shapley evaluate the element or inputs in numerical way by using the “value” of playing game. This game theory concept focus on the interactions among coalitions of players to win a game. For example in a team of five person working together to win a competition, each of player will contribute their skills and teamwork behaviour to win the game. Thus, Shapley Value method is used to identify the importantness of each evaluating factors that contribute in SMED implementation.

Then, the important data from the converting internal setup time to external setup time will be analysed to measure the time reduction process worth or not because the improvement is made from this stage. By using DEA as a model to measure the performance since it can be used to evaluate and improve the performance in production line. From both result, a conclusion can be made on performance of SMED implement in the production line whether the SMED effectiveness achieve successfully or not.

1.7 Thesis Overview

The summary for this work is structured in the following way:

Chapter 1 describes the implementation of SMED in various production line of manufacturing fields. In this chapter focus on how efficient the SMED in reducing time of changeover process throughout its implementation in manufacturing company. The objectives of the research, significance of research and scope of the dissertation also been discussed in this chapter.

Chapter 2 provides the literature review of the keywords for the research. These include SMED, Performance Measurement and recent research of SMED in manufacturing production line.

Chapter 3 explained the flow chart and the methodology to measure the performance of SMED. In this chapter will discuss on the development of DEA model and Shapley Value method to measure SMED performance includes the steps in developing the model.

Chapter 4 shows the data collection will be used to evaluate the SMED effectiveness along in implementation. In this chapter also discuss on results obtained from the inputs and outputs used to measure the SMED performance.

Chapter 5 discussion on the conclusion and some recommendations that could be done in further research.

CHAPTER 2

LITERATURE REVIEWS

2.1 Introduction of Single Minute Exchange of Die (SMED)

Single Minute Exchange of Die (SMED) is one of lean manufacturing tools to reduce changeover time in manufacturing process (Shingo, 1985). On early 1950s, SMED also known as Quick Die Change was develop by Shigeo Shingo has its objective to achieve setup time in less than ten minutes which refer the number of minute expressed by single digits. This tool also used to reduce and simply the setup time during changeover to fulfill high demands for product variability, reduced product life cycles and the need to significantly reduce inventories. Traditionally, setup time is one of the most expensive cost to minimize the number of setup implemented and for large production lots. (Holweg, 2006).

Before SMED is introduced, industries produce large lots to minimized the cost during setup operations and obtain the lowest possible percentage of idle time per unit produced. (Moreira et. al, 2011). The implementation of SMED in automobile industry now is more popular due to the idle amount of each production lot was obtained when the inventory costs equal with the costs of idle equipment during the changeover tools (Min and Pheng, 2007). According to Shingo (1989), setup operations divide into two fundamental which is internal setup and External setup.

Internal setup which internal activities which are performed while the machine is offline and therefore must be minimized because they decelerate the production and external activities that are performed while the machine is running. 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. In order to achieve SMED goals, internal activities need to be converted to external activities wherever possible in order to minimize the changeover setup time.

Shingo (1989) state that setup time in comprised of following four functions;

1. Preparation of materials,dies,fixtures and jigs that takes 30 percents of setup time,
2. Clamping and removing dies and tools that takes 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.

Often changing over from one lot to another require a system to prevent time consuming too much. Earlier stated that SMED Methodology consist of 4 important stages and each stages will be explained as in below;

Stage 1: Preliminary stage

During this stage, first step is to understand the production floor and study the actual conditions in detail. (Robinson, 1990). The setup operations, internal activities setup and external activities setup are not clearly prominent. The most exact to document the data of current state of typical changeover is videotaped the entire changeover process. Next, the data was viewed and observations detail of complete changeover were recorded in details. During changeover process, all work done during machine off known as the internal setup process. While external setup process are the element of changeover happen during the machine is running. This stage need the researcher to understand the element of both internal and external activities.

Stage 2: Separating internal and external setup stage

At this stage, it is important to understand and identify the element of both internal and external activities. By refering at Figure 2.1 during this stage, classification for both setup time are important as well as individual times that required to perform the changeover in the original state. The separating process enable to recognize the importaness of each steps and the contribution of each activities that allows for researches to complete the next stage.

From detail explanation of each stage, Figure 2.1 below shows the summary of conceptual stage designed by Shingo himself and the idea of reduce setup time.

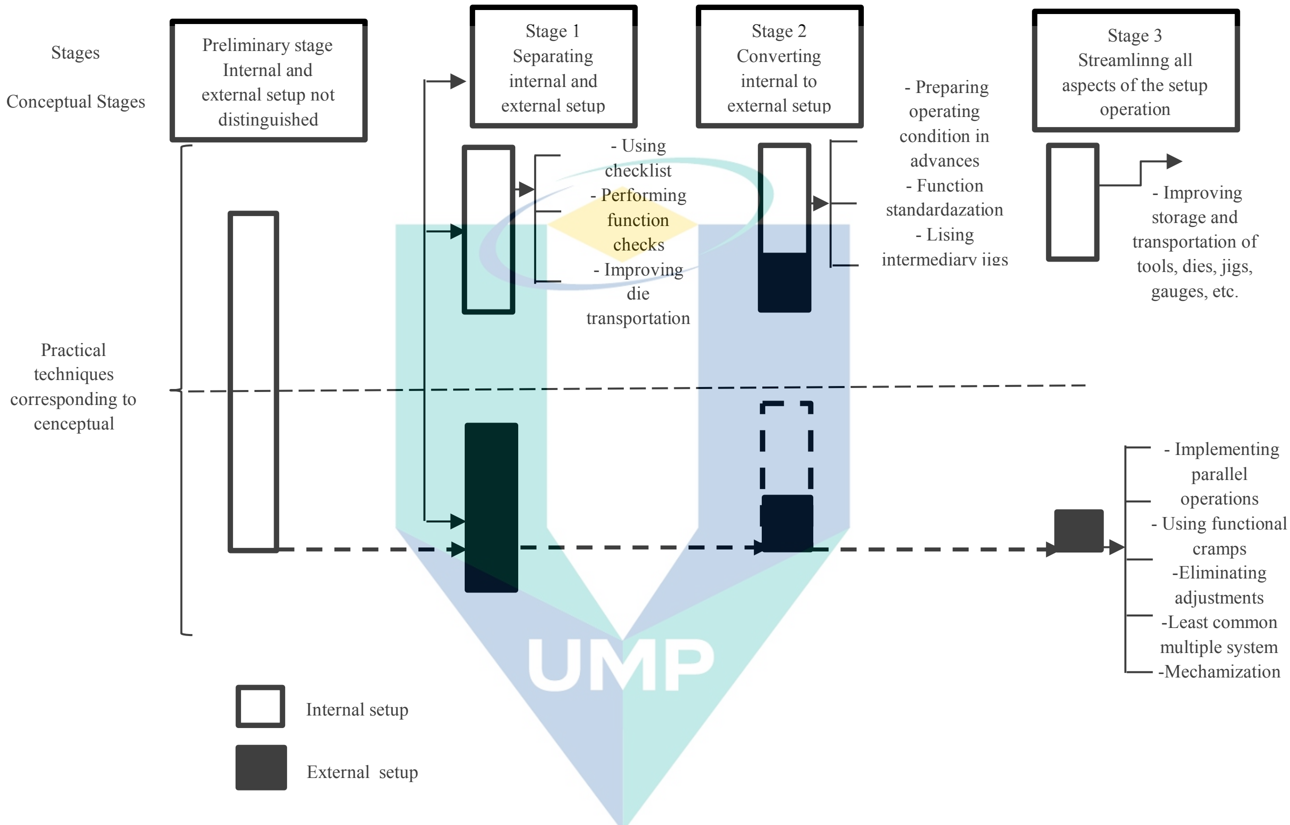

Figure 2.1 The conceptual stage by Shingo

Source: Shingo (1989)

Stage 3: Converting internal to external setup stage

Next, the most critical stage in SMED methodology where conversion of internal setup to external setup. The leading factor is to recognize the preparation of parts or tools involving in the changeover process which give addition to any maintenance activities and so forth should not be done while the machine is stopped. The aim of this is to identify any changeover activities that can be performed while the machine is running, shown in Figure 2.1 as well which in tum leads to a direct reduction in the amount oftime the machine is required to sit idle during the changeover. Mastering the distinction between internal and external setup is the essential task towards achieving SMED (Shingo, 1985).

Stage 4: Streamlining all aspects of the setup operation stage

In this stage, the new procedure will be establish in order to show the precise procedure for each production process and operator's work in changeover process is necessary to perform the new schedule of changeover. In order to ensure the benefit of new method are accomplished, the new changeover procedure will be trained by operators. The time taken of standardizing the setup procedures are documentation to obtain exact data for all shift, variability reduction and activities improvement on production floor. The new changeover plan went smoothly if the data collection of each changeover reach their target or time taken for setup operation reduced from previous data from last production.

Waste is also defined as one of loss item in production and to be specify in SMED the time reduction happen act as waste when the production spend too much time on changeover setup. A study from Goubergen & Landeghem (2002) classify the different reasons for reducing setup times into three main groups:

1. Flexibility – due to the large amount and variety of products and due to the reduction of the quantities requested by customers, a company must be prepared to quickly react to customers' needs;
2. Bottlenecks capacity – especially in these cases, every minute lost is crucial. Setups should be minimized to maximize the available capacity for production;
3. Costs minimization – production costs are directly related to the equipment´s performance. With setup time reduction, machines stop during less time, thus reducing production costs.

2.2 Application of Single Minute Exchange of Die (SMED)

The application of SMED widely used as lean tools for reducing setup changeover time in certain production line where limitation time become their main focus in the changeover process. In automobile industry, frequent changing die or mold is a must during production process to produce one complete part. A study conducted by Mansor et al. (2014) in metal stamping industry involve producing automotive part had implemented SMED in their factory. In the research, data collection after SMED approach the production line shows the factory managed to reduce changeover setup time from 32 minutes to 12 minutes. A study by Mohamed Esa et al. (2015) also stated by applied SMED methodology, it reduce time from 45 minutes to 28 minutes after five months improvement in automotive manufacturing. The application of SMED helps the manufacturer to reduce the time consume during manufacturing process causes the production process to be faster since this method is suitable in automotive industry.

In general, the main goal of SMED is to reduce changeover setup time and mostly researchers continue this knowledge by applying in various production line. Che Ani and Shafei (2014) focused on improving the productivity on CNC machine process through implementation of SMED techniques. In the study, the result shows the productivity is increased from 93% to 95.6% while for the machine changeover time are reduced to 28.5% after the SMED was implemented. Another study from Bajpai (2014) also conduct a study on garment and textile production reduce 113 minutes to 90 minutes on machine setting time after implement SMED hence, increase the productivity of changeover process and reduce time production. Research done by Kumar and Bajaj (2015) also state that by implementation of SMED in mechanical press machine reduce total setup time to 69 minutes from 265 minutes. In Gabahne et al (2014) research, SMED eliminates 44 minutes which makes the total time taken to perform the operation was decreased by 54 percent for the injection molding production line.

In most cases, time reduction were their research's objective, shown as well as in a study by Joshi and Naik (2012) in small scale industry have affected the production reducing time from 480 sec to 385 sec which decreased by 20%, other than data collection also shown enhancement of product from 4200 to 4400 units. Apart from the reduction time of changeover process, the quantity of demands increase in researchers studies which also another excellent outcome from application of SMED in industry. In Azizi and Manoharan (2015) research, SMED is used to reduce the changeover time at the insertion process of PCB assembly line where the SMED successfully reduce the machine setup time from 145 seconds to 54 seconds. In this study, the SMED and Kaizen is designed as improvement process to reduce the work-in-progress (WIP) and lead time.

From studies conducted by researchers, unnecessary time is a waste in production process because it leads to longer process and longer process leads to large amount of money wasted thus effect the productivity. A research by Brito et al (2017) for turning production area, through SMED tools the setup time has reduced to 46% hence overcome the productivity problems and fulfill the high customer demands. The author stated, that this improvement has increase the productivity of whole operation by 24%. In other study conducted by Rosa et al (2017) mentioned, SMED has reduced the stoppage time on the line to execute setups by at least 58.3%, corresponding to 210 min. This improvements causes the tuning technicians were no longer needed; the setup at the workstations was ensured by the operators themselves, with the exception of the change in references.

Other than that, most research focus on SMED methodology to reduce time in various field include in aluminum profiles extrusion production system by Isme and Assaf (2012). From authors research, the setup process improved by 15% of the time which coincide about 60,000 dollars per year. Numerous studies have attempted to explain the benefit of SMED in reducing setup time include in Bevilacqua et al (2015) gives setup instructions and guidelines for preparing the standardized SMED setup procedure without ignoring the actual constraints in a pharmaceutical company. Based on Karam et al (2018) case study in pharmacheutical industry stated that the SMED has decreased the changeover time at the bottleneck process by 30% in 12 months. In author's project, SMED have increased the process standardization, achieved higher customer satisfaction reflected by improved flexibility of changeovers.

SMED methodology is one of factors which contribute to the effectiveness of time reduction process because without appropriate steps SMED's goal will not achieved. Additionally, standardized the setup operations and a properly flow of process effect the operator to become more fast and intuitive. Ulutas, (2011) and Costa et al. (2013) mentioned that by numerating all the changeover steps in a proper order to assure an efficient and standard process will be established and spare steps can be removed. A research by Mistry and Desai (2015) stated SMED methodology enable the time reduction in changeover process through company's internal resources reconstruction without the significant additional expenditure. SMED implementation not only efficient for manufacturing improvement but also for equipment or die design development.

Another research conducted by Michels (2007) in reducing time of changeover punch press occur in fabrication department at KI Manitowoc. In author study, six steps are applied in SMED methodology to achieve time reduction include final steps is changeover procedure should be standardized in order to find out the continuous of production. Research by Simoes and Tenera (2010) mentioned that SMED methodology is applied to improve the press line by do some improvement for the internal operations by installation of a suitable equipment to enable a tool exchange more efficient. The authors is suggested the use of Gantt chart in SMED's time study in order to consider parallelism between operations for fully study the process duration.

Studied by Costa et al. (2013) in a metal-mechanic area of an elevators company using SMED methodology using mechanical press machine, the researcher develop a solutions it was possible to reduce setup times, work-in-process (WIP) and distances travelled by operators. Kayis and Kara, (2007) suggested there are three categories to conclude from the result obtain in his research which is Mechanical improvements, Procedural improvements and organizational improvements. The author also found the setup reduction (SUR) is an extremely valuable approach in modern manufacturing. Company implement the SMED can improve the time taken for changeover process but also improvement can be achieve in the term of productivity. Research by Patel, Shaw and Dale (2001) discussed on main barriers to implementation of setup time reductions and mistakes happen while performing SMED. Authors also stated that understanding SMED methodologies also important before practicing in production line because the maximum time reduction can be made if unnecessary activities is reduced.

Based on the research done along these two decades, many improvement had been made since SMED is introduced, in term of time reduction its achieve the company request in order to increase the productivity. Apart from the main purpose of their studies are to produce small batch within short time, increase productivity and reduce inventory, the performance of SMED along the process is not been measured. Thus by measuring the performance of SMED along the reduction time process can indicate the effectiveness of SMED throughout its implementation. In this research, performance of SMED will be measured to identify the effectiveness of SMED.Another equally important style is the caption.

2.3 Performance Measurement

From the last two decades, Neely (1999) suggest that the performance measurement is practically advantageous and cost-effective way to measure the performance in production line. This intention came up when abundant authors discuss on many problems appears in the performance measure used by industry. Neely et al. (1995) stated that performance measurement means the process of quantifying the efficiency and effectiveness of action. Efficiency can be refers when the supplier meet the customer requirement while effectiveness refers on how economically the firm's resources when provide material, measure the level of customer satisfaction. Figure 2.2 shows a framework for performance measurement system that was designed by Neely et al. (1995). The performance measurement can be analyze based on these three different levels;

1. The individual performance measures;
2. The set of performance measures (the core of performance measurement system)
3. The relationship between the performance measurement system and the environment within which it operates.

From the Figure 2.2, Neely (1995) suggested that there are four categories that include in individual measurement which are quality, time, cost and flexibility.

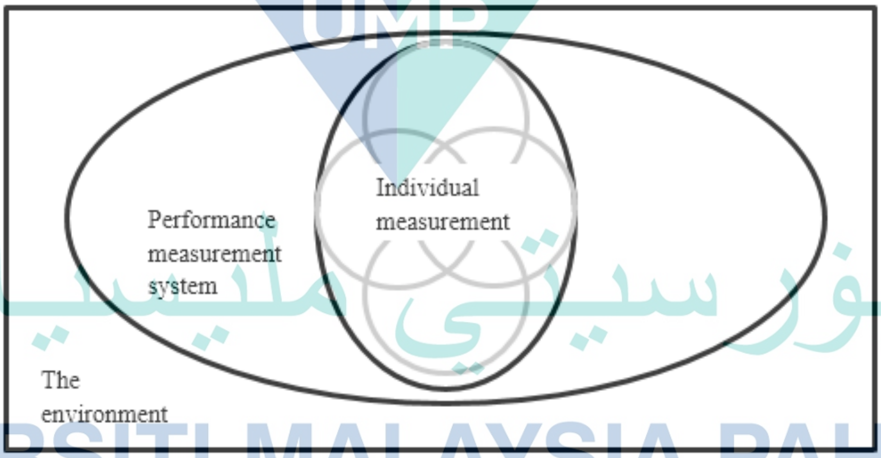

Figure 2.2 Framework for Performance Measurement
Source: Neely et. al. (1995)

Frigo (2003) claimed that most companies target on performance measures related with strong correlation or relationship between internal processes and customer needs on their targeted market. Since customer satisfaction is important, Malone and Sinnett (2005) insisted by doing benchmarking and right routine can yield a positive result and beware of wrong decision by repetition of same routine and process.

2.3.1 Performance Measuring Framework

Lockamy III (1991) suggested that four theoretical performance measurement system for dimension of cost, quality, lead time and delivery based link between operational and strategic PM systems in small number of world-class manufacturing companies. A performance measurement framework assists in the process of performance measurement system building, by interpreting performance measurement boundaries, defining the performance measurement dimensions and may also provide initial ideas on relationship between performance measurement dimensions. Folan and Browne (2005) conclude the suggestion for design and improvement of performance framework based on two framework typology which is procedural and structural.

Structural framework give focus on measures management while procedural framework focus on measures on strategy. A research done by Azzone et al. (1991) develop a structural PM models to suit specific competitive priorities which to measures based upon an internal/external division. Another studies by Kaydos (1991) and Wisner and Fawcett (1991) have proposed procedural framework model, while the structural balanced scorecard proposed by Kaplan, Norton (1992) introduced the concept of producing a ‘‘balanced’’ set of measures of non-financial measures ‘‘balanced’’ against financial measures. Yeniyurt (2003) develop a model that use a cross-process approach and five levels of measurement performance: financial, consumer, internal processes, innovation and corporate culture/climate. Another structural framework done by Rouse and Putterill (2003) attempts an integration of a number of structural frameworks includes a set of principles that should be considered alongside the framework.

2.4 Data Envelopment Analysis (DEA)

Data envelopment analysis (DEA) is a linear programming methodology to measure the relative performance of organizational units in the presents of multiple inputs and outputs. DEA is a non-parametric method to estimate the production boundary in operations research and economics. It also used in empirically measure productive efficiency of decision making units (or DMUs). The efficient of DMU is told to be 100% if none of the outputs can be increased without either increasing one or more inputs; or decreasing some of the other outputs and vice versa. (Sherman and Zhu, 2006). Although DEA has a strong link to production theory in economics, the tool is also used for benchmarking in operations management, where a set of measures is selected to benchmark the performance of manufacturing and service operations.

Moreover, every organization can gain benefit from DEA in various ways since it can be adapted to improve service productivity. Increased use by service managers will identify new strengths and benefits that can be derived from DEA along with gaps and weaknesses. In DEA, it compares service units considering all resources used and services provided, and identifies the most efficient units or best practice units (branches, departments, individuals) and the inefficient units in which real efficiency improvements are possible. This is achieved by comparing the mix and volume of services provided and the resources used by each unit compared with those of all the other units. In short, DEA is a very powerful benchmarking technique.

Other than that, DEA benefits to organization since it can calculates the amount and type of cost and resource savings that can be achieved by making each inefficient unit as efficient as best practice units. Any specific changes in the inefficient service units are identified, which management can implement to achieve potential savings located with DEA. These changes would make the efficient units performance approach the best practice unit performance. In addition, DEA estimates the amount of additional service an inefficient unit can provide without the need to use additional resources. (Sherman and Zhu, 2006).

Thus, management receives information about performance of service units that can be used to help transfer system and managerial expertise from better-managed, relatively efficient units to the inefficient ones. This has resulted in improving the productivity of the inefficient units, reducing operating costs and increasing profitability because DEA evaluate multiple inputs and multiple outputs. Therefore from DEA calculation, most efficient if the efficiency obtains a score of one and is inefficient if the score is less than one.

Assuming that there are n DMUs for the model, each with m inputs and s outputs, the relative efficiency score of a target DMU_0, θ_0 is obtained by solving the following model proposed by Charnes et al. (1978).

$$\text{Max} \quad \theta_0 = \frac{u_1 y_{1o} + u_2 y_{2o} + \cdots + u_s y_{so}}{v_1 x_{1o} + v_2 x_{2o} + \cdots + v_m x_{mo}} = \frac{\sum_{r=1}^{s} u_r y_{ro}}{\sum_{i=1}^{m} v_i x_{io}} \qquad 2.1$$

Subject to:

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

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 output generated by the DMU

u_r: weight assigned by DEA to output r

v_i: weight assigned by DEA to input i

DMU_o is the target DMU and this calculation will be repeated by changing the target DMU. The fractional program shown as (2.1) can be converted to linear program as shown in (2.2).

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

subject to:

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

$$\sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} \leq 0 \qquad j = 1,2, \ldots, n \qquad 2.2$$

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

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

2.5 Shapley Value

Cooperative game theory is one of the two correspondence of game theory where it focus on the interactions among coalitions of players. Core is a solution concept that assigns to each cooperative game, the set of payoffs that no coalition can improve upon or block. In a context in which there is unfettered coalitional interaction, the core arises as a good positive answer to the question posed in cooperative game theory. In other words, if a payoff does not belong to the core, one should not expect to see it as the prediction of the theory if there is full cooperation. Shapley value is a solution that describes a single payoff for each player, which is the average of all marginal contributions of that player to each coalition. It is usually viewed as a good normative answer to the question posed in cooperative game theory. That is, those who contribute more in groups that include them should be paid more. (Roth A. E., 1988)

In Roth A. E. (1988) writings, the core of game theory was proposed by Francis Ysidro Edgeworth in 1881 and the reinvented version by Lloyd Shapley which defined in game theoretic terms. Thus, the Shapley value was proposed by Lloyd Shapley in his 1953 PhD dissertation. Both the core and the Shapley value have been applied widely, to shed light on problems in different fields, including economics and political science. The method of Shapley Value to evaluate each element in numerical way by using the "value" of playing game and now has grew within some research and continue until now. This concept is used because it has become central solution concept in cooperative game theory depends on the coalition that contribute by the players.

The Shapley value has been explained where its domain has been extended and made more specialized. The same value function has been derived from apparently quite different assumptions. Thus, the whole families of related value functions have been found to arise from relaxing several of the assumptions. The reason Shapley value has been the focus of in many interest is that it represents a distinct approach to the problems of complex strategic interaction that game theory seeks to illuminate. In von Neumann and Morgenstern (1947) research, the first step is to summarize each alternative facing an individual decision maker by a single number. Their solution to this problem expected utility theory has left its own indelible mark on economic theory, quite independently of the impact the theory of games had.

Briefly, von Neumann and Morgenstern (1947) contribution was to specify conditions on an individual's preferences over possibly risky alternatives sufficient so that his choice behavior could be modeled as if, faced with a choice over any set of alternatives, he chose the one that maximized the expected value of some real-valued function, called his utility function. In this way, a complex probability distribution over a diverse set of alternatives could be summarized by a single number, equal to the expected utility of the lottery in question. Having reduced the alternatives facing each individual to a numerical description, von Neumann and Morgenstern proceeded to consider (among other things) a class of games in which the opportunities available to each coalition of players could also be described by a single number. (Roth, 1977)

In extended knowledge, they 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 $N = (1,\ldots, n)$ is called a coalition. The record for the coalition S is defined by; (Shapley, 1953)

$$x_i(S) = \sum_{j \in S} x_{ij} \qquad (i = 1, \ldots., m) \tag{2.3}$$

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

This coalition aims at obtaining the maximal outcome c(S):

$$\mathrm{c(S)} = \sum_{i=1}^{m} w_i \, x_i(S) \tag{2.4}$$

Subject to;

$$\sum_{i=1}^{m} w_i = 1 \qquad w_i \geq 0(\forall_i) \tag{2.5}$$

The $c(S)$, with $c(\varnothing)=0$, 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:

2.6

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

With weights of probability to enter into a coalition *S* defined as following:

$$\gamma_n(S) = \frac{(s-1)!\,(n-s)!}{n!} \qquad 2.7$$

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

It is a solution that define a conclusion for each player, which is the average of all marginal contributions of that player to each coalition. By using the concept of 'game theory', we can identify how important the player and the elements that contribute in their game. In this research, Shapley Value is used to measure the efficiency of each machines, which contribute more to production line. The player and element of contributor can be identified according to the variables that researchers want to measure.

2.6 Moving Coalition Analysis (MCA)

Moving Coalition Analysis (MCA) is a method to observe performance trends of coalition over time. The calculation steps for MCA is similar with Shapley Value but the difference is each period in a sub-coalition formed by several periods or players is measured. A coalition is divided into several sub-coalitions where each sub-coalition should consist of three or more players. (Mansor & Ohsato, 2010). A sub-coalition drops one of its members and picks up a new member to form the next sub-coalition and move horizontally where the row (X-axis) is the player and the column (Y axis) is the contributor.

Let a coalition consists of *m* players with *n* contributors and a sub-coalition consists of *k* players. ($K \geq 3$). Then, we will have S=(n-K+1) sub-coalitions. For example shown in Table 2.1, let m=5 and K=3, then the number of sub-coalition *S* is 3. In this example, the number of players m=6, and the number of players in each sub-coalition K=3. Therefore, the number of sub-coalitions S=4. Each sub-coalition is shown in Table 2.2 until Table 2.5.

Table 2.1 Example of Moving Coalition Analysis

Player / **Contributor**	***t*₁**	***t*₂**	***t*₃**	***t*₄**	***t*₅**	***t*₆**
C_1	D_{11}	D_{12}	D_{13}	D_{11}	D_{11}	D_{16}
C_2	D_{21}	D_{22}	D_{23}	D_{21}	D_{21}	D_{21}
….	…	…	…	…	…	…
C_{n+1}	$D_{(n-1)1}$	$D_{(n-2)2}$	$D_{(n-3)3}$	$D_{(n-4)4}$	$D_{(n-5)5}$	$D_{(n-6)6}$
C_n	D_{n1}	D_{n2}	D_{n3}	D_{n4}	D_{n5}	D_{n6}

Table 2.2 1st sub-coalition

Player / **Contributor**	t_1	t_2	t_3	**Sum**
C_1	D_{11}	D_{12}	D_{13}	$D_1 = D_{11} + D_{12} + D_{13}$
C_2	D_{21}	D_{22}	D_{23}	$D_2 = D_{21} + D_{22} + D_{23}$
….	…	…	…	…
C_{n+1}	$D_{(n-1)1}$	$D_{(n-2)2}$	$D_{(n-3)3}$	$D_{(n-1)} = D_{(n-1)1} + D_{(n-2)2} + D_{(n-3)3}$
C_n	D_{n1}	D_{n2}	D_{n3}	$D_n = D_{n1} + D_{n2} + D_{n3}$

Table 2.3 2nd sub-coalition

Player / **Contributor**	t_2	t_3	t_4	**Sum**
C_1	D_{12}	D_{13}	D_{14}	$D_1 = D_{12} + D_{13} + D_{14}$
C_2	D_{22}	D_{23}	D_{24}	$D_2 = D_{22} + D_{23} + D_{24}$
….	…	…	…	…
C_{n+1}	$D_{(n-2)2}$	$D_{(n-3)3}$	$D_{(n-4)4}$	$D_{(n-1)} = D_{(n-1)2} + D_{(n-1)3} + D_{(n-1)4}$
C_n	D_{n2}	D_{n3}	D_{n4}	$D_n = D_{n2} + D_{n3} + D_{n4}$

Table 2.4 3[rd] sub-coalition

Player / Contributor	t_3	t_4	t_5	Sum
C_1	D_{13}	D_{14}	D_{15}	$D_1 = D_{13} + D_{14} + D_{15}$
C_2	D_{23}	D_{24}	D_{25}	$D_2 = D_{23} + D_{24} + D_{25}$
....	...	...	...	...
C_{n+1}	$D_{(n-3)3}$	$D_{(n-4)4}$	$D_{(n-4)4}$	$D_{(n-1)} = D_{(n-1)3} + D_{(n-1)4} + D_{(n-1)5}$
C_n	D_{n3}	D_{n4}	D_{n5}	$D_n = D_{n3} + D_{n4} + D_{n5}$

Table 2.5 4[th] sub-coalition

Player / Contributor	t_4	t_5	t_6	Sum
C_1	D_{14}	D_{15}	D_{16}	$D_1 = D_{14} + D_{15} + D_{16}$
C_2	D_{24}	D_{25}	D_{26}	$D_2 = D_{24} + D_{25} + D_{26}$
....	...	...	...	...
C_{n+1}	$D_{(n-4)4}$	$D_{(n-4)4}$	$D_{(n-6)6}$	$D_{(n-1)} = D_{(n-1)4} + D_{(n-1)5} + D_{(n-1)6}$
C_n	D_{n4}	D_{n5}	D_{n6}	$D_n = D_{n4} + D_{n5} + D_{n6}$

Assume that φ_{sn} is the Shapley value in a sub-coalition (Table 2.6). Then benchmark the Shapley Value obtained from each sub-coalition against the best value of each sub-coalition. For example, let φ_{11}, φ_{12}, φ_{13},…, φ_{1k} are the Shapley value in a sub-coalition and φ_{12} is the best Shapley value in this sub-coalition. Then, we divided each φ_{11}, φ_{12}, φ_{13},…, φ_{1k} by φ_{12} and obtained, θ_{11}, θ_{12}, θ_{13},…, θ_{1k} shown in Table 2.7.

$$\theta_{sn} = \varphi_{sn} / (best \text{ Shapley value of sub-coalition } s) \qquad 2.8$$

This value is called as "Scale of Balance (SoB)". The allocation for each player is derived from combinations of player's contributions. High contribution with a good balance of combinations will lead to higher allocation to the player. We defined this phenomenon as SoB=1. MCA is used to evaluate the collaboration of activity of internal and external with time consumed for each activities in SMED.

Table 2.6 The Shapley Value

Player / Contributor	t_1	t_2	t_3	$\dots$	t_k	t_{k+1}	$\dots$	t_s	t_{s+1}	$\dots$	t_{N-1}	t_N
1st sub-coalition	φ_{11}	φ_{12}	φ_{13}	$\cdots$	φ_{1k}							
2nd sub-coalition		φ_{22}	φ_{23}	$\cdots$	φ_{2k}	φ_{2k+1}						
$\vdots$												
sth sub-coalition								φ_{ss}	φ_{ss+1}	$\cdots\varphi_{ss+k}$		
$\vdots$												
Sth sub-coalition										φ_{SN-k+1} $\dots$	φ_{SN-1}	φ_{SN}

Table 2.7 Average SoB

Player / Contributor	t_1	t_2	t_3	$\dots$	t_k	t_{k+1}	$\dots$	t_s	t_{s+1}	$\dots$	t_{N-1}	t_N	**Avg SoB**
1st sub-coalition	θ_{11}	θ_{12}	θ_{13}	$\cdots$	θ_{1k}								θ_1
2nd sub-coalition		θ_{22}	θ_{23}	$\cdots$	θ_{2k}	θ_{2k+1}							θ_2
$\vdots$													
sth sub-coalition								θ_{ss}	θ_{ss+1}	$\cdots\theta_{ss+k}$			θ_s
$\vdots$													
Sth sub-coalition										θ_{SN-k+1}	θ_{SN-1}	θ_{SN}	θ_S

2.7 Transpose Moving Coalition Analysis (TMCA)

For Transpose Moving Coalition Analysis (T-MCA), the position of player and contributor is transposed. In MCA, periods and contributors are in X and Y axis, respectively. However, in T-MCA, periods are located in the Y axis and contributors in the X axis where the example is shown in Table 2.8. Then the sub-coalitions vertically is created based on Table 2.8 from 1st sub-coalition until 4th sub-coalition. (Table 2.9 to Table 2.12)

Table 2.8 Transpose from Table 2.2

Player / **Contributor**	C_1	C_2	…	C_{n-1}	C_n
t_1	D_{11}	D_{12}	…	$D_{(n-1)1}$	D_{n1}
t_2	D_{12}	D_{22}	…	$D_{(n-2)2}$	D_{n2}
t_3	D_{13}	D_{23}	…	$D_{(n-3)3}$	D_{n3}
t_4	D_{14}	D_{24}	…	$D_{(n-4)4}$	D_{n4}
t_5	D_{15}	D_{25}	…	$D_{(n-5)5}$	D_{n5}
t_6	D_{16}	D_{26}	…	$D_{(n-6)6}$	D_{n6}

Table 2.9 1st sub-coalition for TMCA

Player / Contributor	C_1	C_2	…	C_{n-1}	C_n	Sum
t_1	D_{11}	D_{12}	…	$D_{(n-1)1}$	D_{n1}	D_1
t_2	D_{12}	D_{22}	…	$D_{(n-2)2}$	D_{n2}	D_2
t_3	D_{13}	D_{23}	…	$D_{(n-3)3}$	D_{n3}	D_3

Table 2.10 2nd sub-coalition for TMCA

Player / **Contributor**	C_1	C_2	…	C_{n-1}	C_n	**Sum**
t_2	D_{12}	D_{22}	…	$D_{(n-2)2}$	D_{n2}	D_2
t_3	D_{13}	D_{23}	…	$D_{(n-3)3}$	D_{n3}	D_3
t_4	D_{14}	D_{24}	…	$D_{(n-4)4}$	D_{n4}	D_4

Table 2.11 3rd sub-coalition for TMCA

Player / Contributor	C_1	C_2	…	C_{n-1}	C_n	Sum
t_3	D_{13}	D_{23}	…	$D_{(n-3)3}$	D_{n3}	D_3
t_4	D_{14}	D_{24}	…	$D_{(n-4)4}$	D_{n4}	D_4
t_5	D_{15}	D_{25}	…	$D_{(n-5)5}$	D_{n5}	D_5

Table 2.12 4th sub-coalition for TMCA

Player / Contributor	C_1	C_2	…	C_{n-1}	C_n	Sum
t_4	D_{14}	D_{24}	…	$D_{(n-4)4}$	D_{n4}	D_4
t_5	D_{15}	D_{25}	…	$D_{(n-5)5}$	D_{n5}	D_5
t_6	D_{16}	D_{26}	…	$D_{(n-6)6}$	D_{n6}	D_6

The procedures to obtain the Shapley Value and SoB for TMCA are the same as shown in MCA part in Table 2.6. The TMCA is evaluated the collaboration of time consumed with the activity of internal and external involved in SMED. Both result from MCA and TMCA will display the fair distributions of each contributor's contribute to the SMED.

2.8 Summary

This chapter was discussed the literature review about the introduction of SMED and its application along two decades in various field in manufacturing industries. The performance measurement was mentioned since it is practically advantageous and cost-effective way to measure the performance in production line. The method used in this research is Data Envelopment Analysis (DEA) and Shapley Value were discussed in this chapter where it measure the performance of SMED along its implementation while Shapley Value measure the fair distribution of SMED activities respectively. Moving Coalition Analysis (MCA) and Transpose Moving Coalition Analysis (TMCA) is to is to observe performance trends of coalition over time.

CHAPTER 3

METHODOLOGY

3.1 Research Procedure

The detail of project methodology will be discussed in this chapter. There are five phases to complete this research, which;

Phase 1: Research Strategy
Phase 2: Detailed data collection on SMED activities
Phase 3: Calculate the efficiency using DEA model
Phase 4: Calculate the fair distribution using Shapley Value
Phase 5: Calculate the fair distribution in time series using MCA & TMCA
Phase 6: A proposed method

3.2 Research Flowchart

Figure 3.1 shows the process flow on how this research is conducted in manufacturing production line.

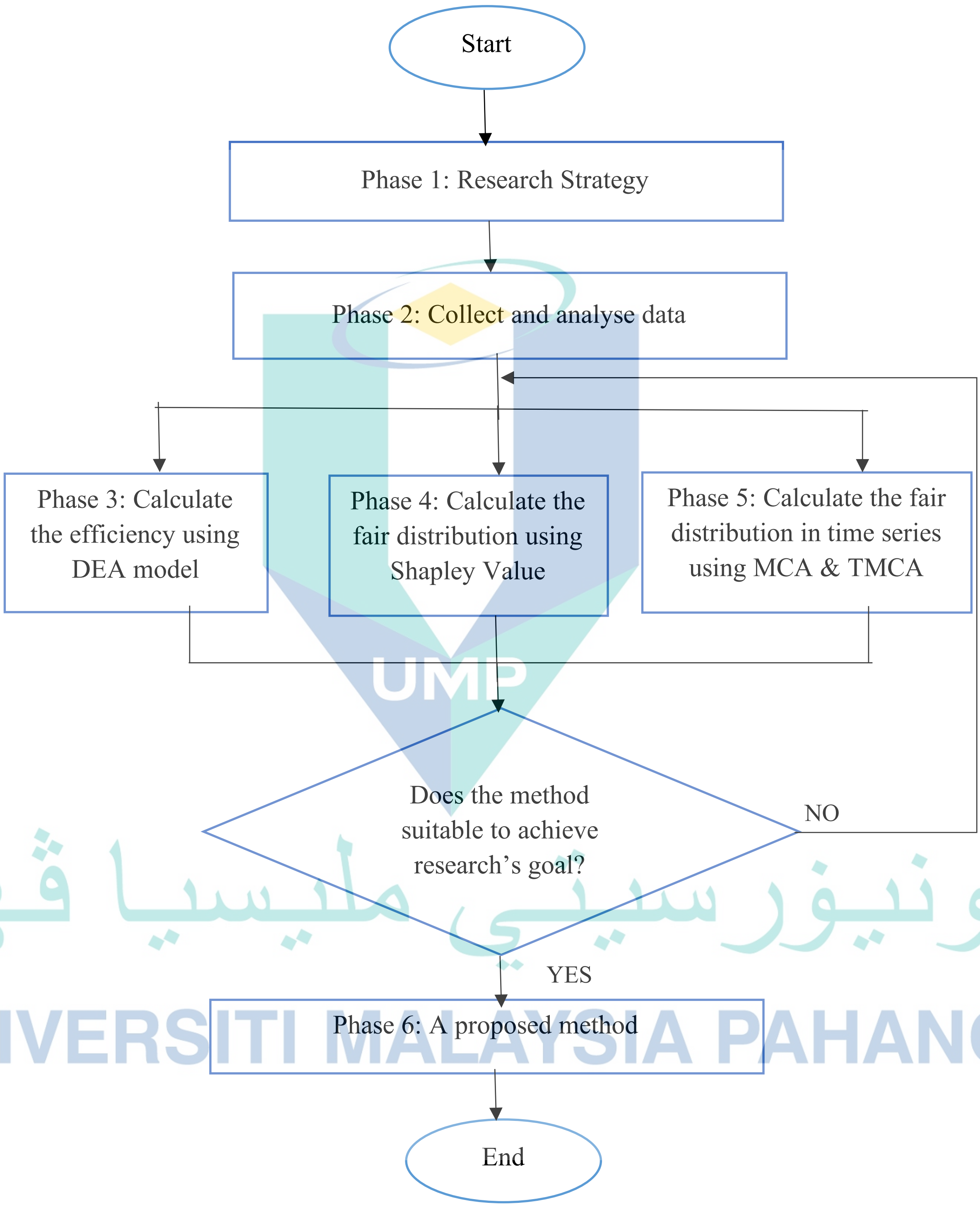

Figure 3.1 The Flowchart for Methodology

3.3 Company Background

The selected company is developing, manufacturing and supplies of metallurgical parts in automotive industries. This production plant produces small and medium size of metal stamping part for Malaysia's national car manufacturers. The production line for metal stamping consists of one of 600 ton press machine and 3 units of 400 ton press machine as shown in Figure 3.2. The area occupied 50% of the production area. This company also implemented SMED from 2011 until now since the changing die in manufacturing industry is frequently done. Thus, shorten the changeover process may contribute to reduction of production time.

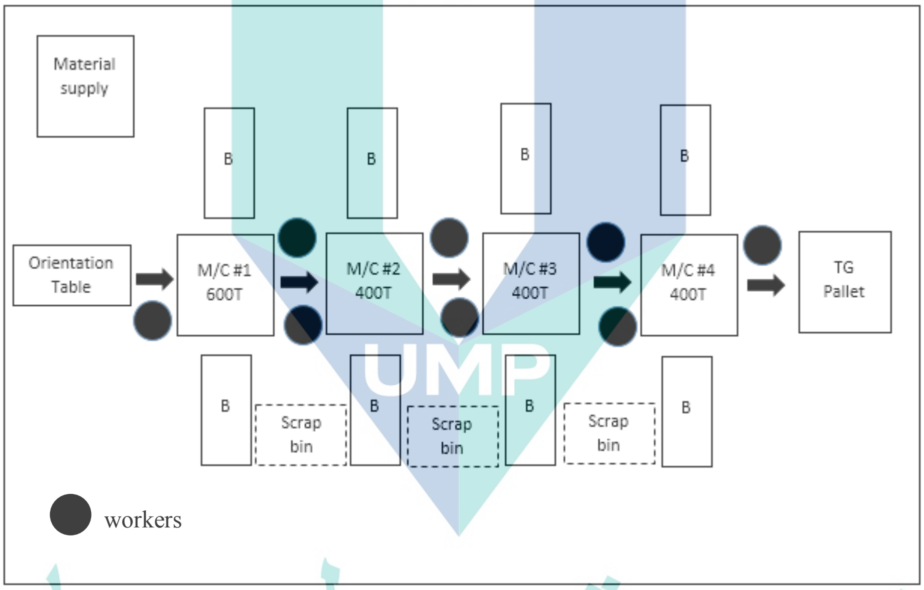

Figure 3.2 Machine layout in the company

3.4 Phase 1: Research Strategy

The research first undergo with collecting and gathering the knowledge from previous research which related to the objective of this study. This process is focused on how SMED methodology has reduced time in changeover activities and what improvement that occur during its implementation. Other than that, all information gather gives appearance about the important of performance measurement during the SMED implementation because all previous research more focus on reducing time in changing die. Further research needed to understand how Shapley Value method and DEA model are applying in measuring SMED performance to ensure the adequate methods for this study. The application of DEA in industries especially focus on production line and its findings throughout the application. Below are the methods being used in collecting the information:

- Books, Journals and papers from previous study

3.4.1 Books, Journal and Papers from Previous Study

Based on previous studies, SMED has been applied in various production line such as electrical, automotive, garment and textile, pharmaceutical and more in order to reduce the time for changeover process. The studies also contain research problem, research objectives, literature review, methodology, findings, discussion, conclusion and etc. These information could be as a guidance to determine the input and output in this research because some of the researches provide how data collection take place and how SMED methodology is done in right way.

3.5 Phase 2: Detailed Data Collection on SMED Activities

Next step, all related data were collected on SMED activities occurred during machine online and offline since reducing time can be occur during changeover process. It is important to understand the SMED methodology in order to collect the accurate data and avoid foul decision making in future. Changing die is very frequent since there are various type of products stamped in this automobile production line. Actual activities and detailed time was recorded during this process by using video-cam. Then, all the activities involved was listed in checklist sheet and classified accordingly to the sequence of the exchange die process.

Next, each data collected will go through analysis so that the inputs and outputs selection are accurate and suitable for measure the SMED performance. Thus, this steps is important to undergo phase 3 and 4 since all data will be measured to identify SMED efficiency and performance which can bring high expectation to company and also give benefits to their production line.

3.5.1 Internal Setup and External Setup

Changeover die process will occur on different types of products to be produced in production line. Figure 3.3 will explained how the process flow of changeover die occur during machine is running and shutdown. Each activity involved in changeover process can be differentiate to internal setup and external setup. The die preparation for next batch is prepared before the existing process is finished. During external setup, the new die is placed on the bolster before worker push button to move the bolster toward machine. When the current production finish its batch, the machine will stop for next batch. Then, the bolster is carried new die will move to machine and new die is inserted. Meanwhile, the old die that coming out from the machine is transferred to die storage during internal setup.

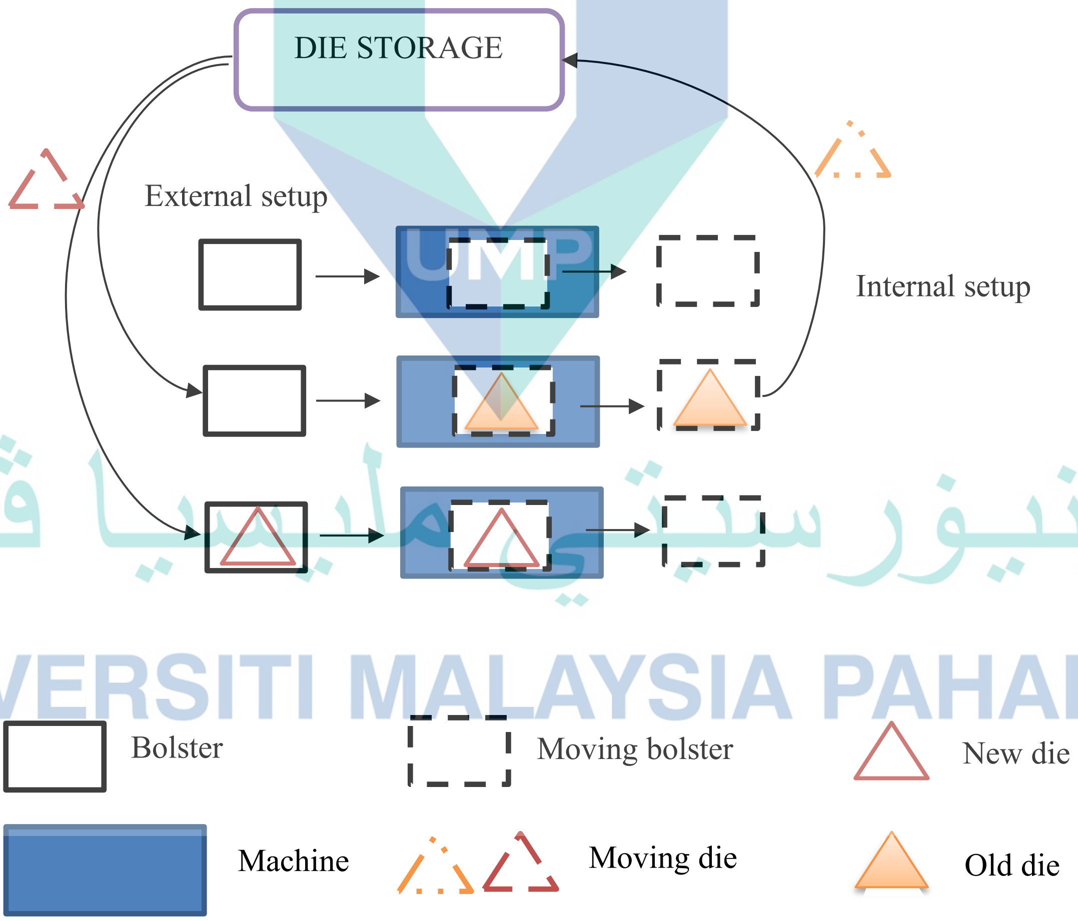

Figure 3.3 Changeover die process flow

3.6 Phase 3: Calculate the Efficiency using DEA Model

DEA model is applied to measure the efficiency of time consume during the whole changeover process to show the effectiveness of SMED implementation in the production line. The purpose of this exercise is to observe the efficiency of time reduction throughout the SMED application. The effectiveness of time reduction should be calculated to determine whether time reductions are worthwhile in line with changes in productivity and production time.

At the early of this phase, a software of DEA-solver has been installed. This software will used for test the suitability of model with DMU selected. During measurement process, all relevant parameters needed in developing a DEA model. A practical DEA model is form on the multiple inputs and multiple outputs collected based on SMED methodology in production line. The model is beneficial because it take into consideration the scale in measuring efficiency which the concept of increasing or decreasing efficiency based on size and output levels can be acknowledge.

Next, internal activities setup and external activities setup are divided according which activities is done while machine is offline or online. The measurement of SMED performance depends on how excellent converting process of internal setup to external setup. Then, each time is recorded and a table of data is filled with time consumed for each SMED activities in selected production line which had been implement the SMED for four years. Time consume for each activities was taken from 2011 until 2014 and those years are treated as DMUs. The time for internal activities is considered as input while the time for external activities is represented as output.

The model used in this research is illustrate in Figure 3.4. The main activities for internal setup is removing die, setting die, parameter setting and quality confirmation which can be represented as x_1, x_2, x_3 *and* x_4 respectively. While activities for external setup are moving of new die from storage to bolster, die installation and transportation of material which represented as y_1, y_2 *and* y_3 respectively.

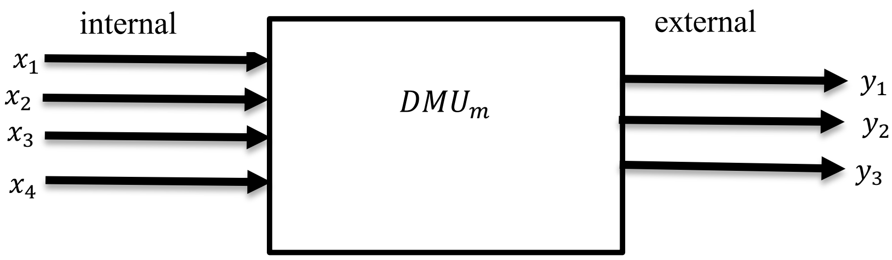

Figure 3.4 Model of the research

In external setup, after transportation of new die from storage and replace it on bolster for next batch is done, the workers will tighten the bolt and nut (die on bolster). During the material preparation, the metal plate will be transported from material storage to the present station ready for the next production.

Table 3.1 Main Internal activity with specific task

Main activity	Task
Remove die	-clean scrap from chute -slide down (make sure indicator show 180) -push unclamp button and take out clamper from die -push clamp button and upper slide -turn bolster button (to left bolster A to right for bolster B) -take out air hose at bolster and put at the machine -push bolster button for bolster moving out
Setting die	-turn bolster button (to left for bolster B and to right for bolster A) -push bolster button to moving in (make sure monitor show icon bolster at home) -upper slide down (make sure up or down die height before slide down) -push unclamp button and slot in clamper -push clamp button and upper slide up
Parameter setting	-setting die height, balance air pressure and cushion pressure -set material on die -push start button and take out to send to QC inspector

Table 3.1 continued

Main activity	Task
Quality confirmation	-check condition part after stamp -QC check part condition base on in-process check sheet -QC confirm part and sign at the part

Table 3.2 External activity conducted

Activity	Task
Remove old die	- Loosen the bolt and nut
New die installation	- Transportation of new die - Workers will tighten the bolt and nut (die on bolster)

3.7 Phase 4: Calculate the Fair Distribution using Shapley Value

In this research, Shapley Value is applied to measure the fair distribution among time that being consumed on each activities that done to complete one set of changeover die process. The measurement will shows the average of all marginal contributions of each time consume in the combinations between the activities and time spend. Thus, it demonstrate how important the both internal and external activities to the SMED.

Based on a Game Theory by Shapley Value, 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. In this research, the fair distribution among measuring factors can be calculate on each machine to identify which machine give minor contribution.

Table 3.3 Activities involves in changeover process

Contributor \ Player	P_1	P_2	P_3	P_4	Sum (J_m)
C_1	t_{11}	t_{12}	t_{13}	t_{14}	J_1
C_2	t_{21}	t_{22}	t_{23}	t_{24}	J_2
C_3	t_{31}	t_{32}	t_{33}	t_{34}	J_3
C_4	t_{41}	t_{42}	t_{43}	t_{44}	J_4

In Table 3.3, a subject that contribute to the activity represent as the player and the element that players contribute to the whole activity represent as the contributor. A player's Shapley Value contribution give 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. For example, in Table 3.3 shows the player involved labelled as P_1, P_2, P_3, and P_4 while contributor that involved represent as C_1, C_2, C_3, and C_4. The time consumed for each activity is denoted by t_{mn}. J_m is the total times spent by each contributor or activity. For example, J_1 is the total time spent to identify the overall image of all setup activities for each machine. From Table 3.3, we normalized the sum to 1 as exhibited in Table 3.4.

Table 3.4 Normalized Data

Contributor \ Player	P_1	P_2	P_3	P_4	Sum (J_m)
C_1	$\frac{t_{11}}{J_1}$	$\frac{t_{12}}{J_1}$	$\frac{t_{13}}{J_1}$	$\frac{t_{14}}{J_1}$	$\frac{J_1}{J_1}$
C_2	$\frac{t_{21}}{J_2}$	$\frac{t_{22}}{J_2}$	$\frac{t_{23}}{J_2}$	$\frac{t_{24}}{J_2}$	$\frac{J_2}{J_2}$
C_3	$\frac{t_{31}}{J_3}$	$\frac{t_{32}}{J_3}$	$\frac{t_{33}}{J_3}$	$\frac{t_{34}}{J_3}$	$\frac{J_3}{J_3}$
C_4	$\frac{t_{41}}{J_4}$	$\frac{t_{42}}{4}$	$\frac{t_{43}}{4}$	$\frac{t_{44}}{J_4}$	$\frac{J_4}{J_4}$

From equation (2.2) in subtopic 2.3, the maximum outcome of c(P_1) is given by;

c(P_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(P_1) can be obtained when w_1=1, w_2 =0, and w_3=0.

From Table 3.3, all coalition's values for each contributor will be enumerated. For example, the value of coalition {P_1,P_2} for contributor C_1 is given as $\frac{t_{11}}{J_1} + \frac{t_{12}}{J_1}$.

Table 3.5 Coalition between players

Player / Contributor	{P_1,P_2}	{P_1,P_3}	{P_1,P_4}	{P_2,P_3}	{P_2,P_4}	{P_3,P_4}
C_1	$\frac{t_{11}}{J_1}+\frac{t_{12}}{J_1}$	$\frac{t_{11}}{J_1}+\frac{t_{13}}{J_1}$	$\frac{t_{11}}{J_1}+\frac{t_{14}}{J_1}$	$\frac{t_{12}}{J_1}+\frac{t_{13}}{J_1}$	$\frac{t_{12}}{J_1}+\frac{t_{14}}{J_1}$	$\frac{t_{13}}{J_1}+\frac{t_{14}}{J_1}$
C_2	$\frac{t_{21}}{J_2}+\frac{t_{22}}{J_2}$	$\frac{t_{21}}{J_2}+\frac{t_{23}}{J_2}$	$\frac{t_{21}}{J_2}+\frac{t_{24}}{J_2}$	$\frac{t_{22}}{J_2}+\frac{t_{23}}{J_2}$	$\frac{t_{22}}{J_2}+\frac{t_{24}}{J_2}$	$\frac{t_{23}}{J_2}+\frac{t_{24}}{J_2}$
C_3	$\frac{t_{31}}{J_3}+\frac{t_{32}}{J_3}$	$\frac{t_{31}}{J_3}+\frac{t_{33}}{J_3}$	$\frac{t_{31}}{J_3}+\frac{t_{34}}{J_3}$	$\frac{t_{32}}{J_3}+\frac{t_{33}}{J_3}$	$\frac{t_{32}}{J_3}+\frac{t_{34}}{J_3}$	$\frac{t_{33}}{J_3}+\frac{t_{34}}{J_3}$
C_4	$\frac{t_{41}}{J_4}+\frac{t_{42}}{J_4}$	$\frac{t_{41}}{J_4}+\frac{t_{43}}{J_4}$	$\frac{t_{41}}{J_4}+\frac{t_{44}}{J_4}$	$\frac{t_{42}}{J_4}+\frac{t_{43}}{J_4}$	$\frac{t_{42}}{J_4}+\frac{t_{44}}{J_4}$	$\frac{t_{43}}{J_4}+\frac{t_{44}}{J_4}$

Coalition {P_1,P_3} and {P_2,P_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.

The combination of Player P_1, P_2, P_3 and P_4 created 24 permutation. In permutation $P_1P_2P_3P_4$, player P_1 is the first comer to the coalition, follows by player P_2, P_3 and finally player P_4, Thus, marginal contribution of each player to coalition can be evaluated as below;

P_4's marginal contribution is;

c({P_1,P_2,P_3,P_4 }) - c({P_1,P_2,P_3})

P_3's marginal contribution is;

c({P_1,P_2,P_3}) - c({P_1,P_2})

P_2's marginal contribution is;

c({P_1,P_2}) - c({P_1})

Lastly, P_1's marginal contribution can be derived from;

c({P_1}) - c({∅})

The same calculation then was repeated for every permutation. The average of 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).

We refer to this score as the "Scale of Balance"(SoB). The SoB was proposed by Mansor and Ohsato (2010) to gives the position of each player against the best-performing player. They defined SoB=1 when a high contribution with a good combination balance from the contributor will lead to higher allocation for the player.

3.8 Phase 5: Calculate the Fair Distribution using Moving Coalition Analysis and Transpose Moving Coalition Analysis

3.8.1 Moving Coalition Analysis (MCA)

For Moving Coalition Analysis (MCA) the calculation is based on the data collection of player and contributor as mention earlier in Chapter 2.6. The player for this exercise is setup time while the contributor is the internal activities and external activities involve in changeover die. The setup time is taken from January 2011 to December 2014 give total of 48 players which labelled as t_1 to t_{48} shown in Table 3.11. The selection of sub-coalition for each period is five players while the contributor consist of four activities from internal part and three activities from external part.

Table 3.6 The Shapley Value

Player / Contributor	t_1	t_2	t_3	$\dots$	t_k	t_{k+1}	$\dots$	t_s	t_{s+1}	$\dots$	t_{N-1}	t_N
1st sub-coalition	φ_{11}	φ_{12}	φ_{13}	$\cdots$	φ_{1k}							
2nd sub-coalition		φ_{22}	φ_{23}	$\cdots$	φ_{2k}	φ_{2k+1}						
$\vdots$												
sth sub-coalition								φ_{ss}	φ_{ss+1}	$\cdots \varphi_{ss+k}$		
$\vdots$												
Sth sub-coalition										φ_{SN-k+1} $\dots$	φ_{SN-1}	φ_{SN}

3.8.2 Transpose Moving Coalition Analysis (T-MCA)

For Transpose Moving Coalition Analysis (T-MCA), the position of player and contributor is transposed. In MCA, periods and contributors are in X and Y axis, respectively. However, in T-MCA, periods are located in the Y axis and contributors in the X axis. Then the sub-coalitions vertically is created as shown in Chapter 2.7 with five players for each sub-coalition. The TMCA is evaluated the collaboration of time consumed with the activity of internal and external involved in SMED. Both result from MCA and TMCA will display the fair distributions of each contributor's contribute to the SMED.

3.9 Phase 6: A Proposed Method

Since most of the companies pay attention on reduce time in changeover process but do not take into account the performance during the entire time reduction process, an approach to measure the performance is suggested. A set of data time consume and activities involved in changeover process is recorded because the main objective is focus on the performance of time reduction process occur in production line. In this research, DEA model is used to measure how efficient time spend for each activity in changeover die. Each DMU will measure the efficiency of each month to identify how efficient the time reduction process take place along SMED implementation throughout three years.

From the result, it give ranking order of input and output contributor separately to show which is more or less efficient. In order to identify which contribute more or less, Shapley Value is used measure the fair distribution on how balanced the production line. This method is used to determine the importance of each contributor in performance measurement from a cooperative game point of view when contributors are the DEA's efficiency. The highest score represent the most contribution to the changeover process. The Scale of Balance (SoB) will show 100 percent as the highest value.

Table 3.5 shows an illustration example on how to determine the contribution of DEA efficiency. The contributor represent the DEA efficiencies which label as θ_1^*, θ_2^* *and* θ_3^*. The actual values for each efficiency as θ_{mn} where m is the number of contributor and n is the number of player. The permutation is generated by the calculation of all coalition values for each player in Table 3.5. Then, every permutation can be evaluated by the marginal contribution of each player to the coalition. Marginal contribution will present how great the contribution of contributor to the process.

Table 3.7 Illustration example

Player / Contributor	P_1	P_2	P_3	Sum
θ_1^*	θ_{11}	θ_{12}	θ_{13}	$\theta_{11}+\theta_{12}+\theta_{13}$
θ_2^*	θ_{21}	θ_{22}	θ_{23}	$\theta_{21}+\theta_{22}+\theta_{23}$
θ_3^*	θ_{31}	θ_{32}	θ_{33}	$\theta_{31}+\theta_{32}+\theta_{33}$

3.10 Summary

In general, this chapter discuss about the flowchart on how this research will be conducted. This research begin with collecting and gathering the knowledge from previous research which related to the objective of this study. It is an imperative to study and understand the SMED methodology before data collection take place to avoid irrelevant data. The SMED should be applied in right way by full understanding of its methodology in order to achieve high level of effectiveness. Findings the parameter that meet the scope for effectiveness measurement is most difficult part. In this research, data time of each activities is validate using DEA model which to measure SMED efficiency while Shapley Value will evaluate the fair distribution among selected players. The results from each method will be compare on which parameters and DMUs shows the best value.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

Based on the previous chapter, the performance measurement of SMED will be measured using DEA while Shapley Value method is used to identify the contribution of each DMU selected in a coalition game to achieve SMED's goal. The result obtained is discussed to understand how each calculation have affected the production line by applied SMED.

4.1 Efficiency Measurement using DEA

In this case study, the DEA model is used for measuring the overall efficiency of SMED by using DEA-solver. The selection of DMU will effect the result because different input and output gives different outcome. The internal setup time is treated as input and external setup time is treated as output because need to identify how well the converting process take place throughout the improvement implemented. From the model described in subtopic 3.6, the calculation is divided into two; where year and months is treated as DMU.

4.1.1 Year as DMU

In this calculation, DMU referred to as the year which will calculate the total amount of time consume for internal activity and external activity shown in Table 4.1. The result based on the score and rank for each DMU is shown in Table 4.2.

Table 4.1 Input and output data by year

Year	I_1	I_2	I_3	I_4	O_1	O_2	O_3
2011	85.5	113	89	97	57	71	48

Table 4.1 continued

Year	I_1	I_2	I_3	I_4	O_1	O_2	O_3
2012	66	101.5	77	87	51.5	61	47.5
2013	52	65	52	71	44	47.5	36.5
2014	45	44.5	31	31	37.5	40.5	30.5

Table 4.2 Result by rank

DMU	Score	Rank
2011	0.907529	4
2012	1	1
2013	1	1
2014	1	1

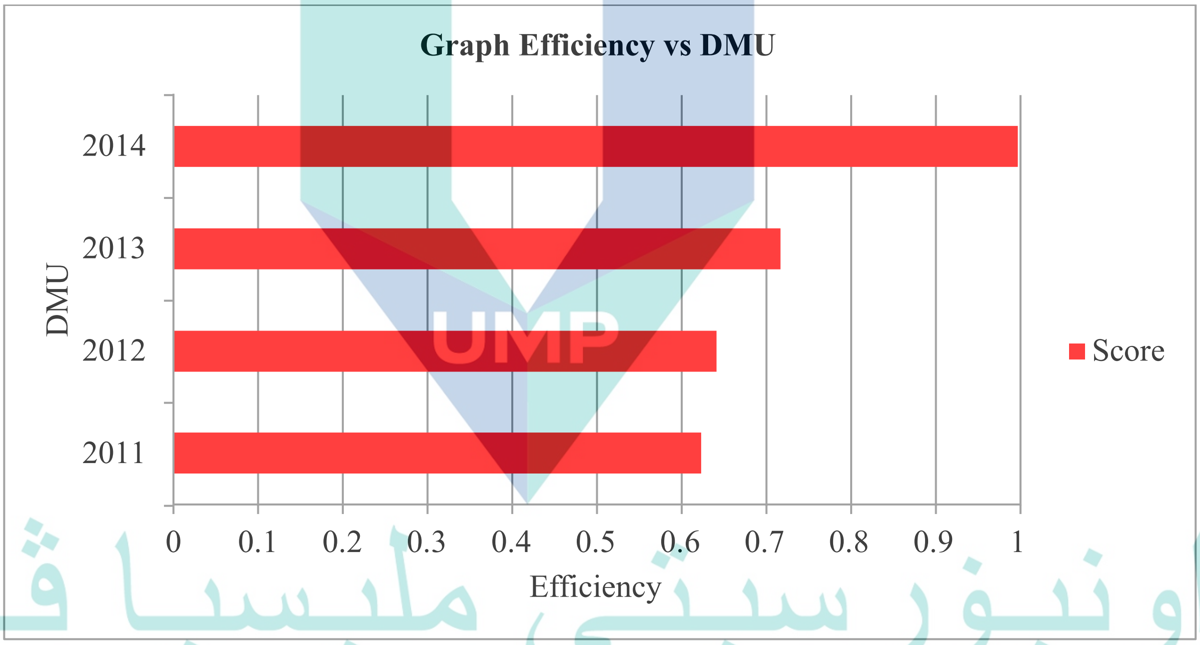

Figure 4.1 Efficiency of SMED by year

The result shown in Figure 4.1 where the performance trends of SMED where the efficiency of changeover time had improved from year to another year since the implementation. Figure 4.1 shows the year 2011 has the least efficiency because SMED has just been applied and changes are still being made to achieve the target time they have set. Table 4.2 shows the best-performing year is 2012, 2013 and 2014 where the efficiency achieved the score of 1. The result by rank shown in Table 4.2 defined the position of each year based on their performance. This position is important to locate the best performance of SMED throughout its implementation. This position will show the which year are efficient. From Table 4.1, the SMED reduce the changeover setup time from 96 minutes to 37 minutes for internal activities based on the subtraction of average time calculated. Then, for external setup time reduce about approximately 20 minutes also based on the subtraction of average time calculated. Therefore, the implementation of SMED in this company is applied effectively by their workers to achieve company's goal in reducing changeover time.

4.1.2 Months as DMU

Then, the months is referred to as the DMU will calculate the average time allocated to exchange die in that month along the year shown in Table 4.3 by using the CCR model as well. Thus efficiency of this converting process need to be measure to identify how reduction time process of internal activities effecting the external activities.

Table 4.3 Input and output data by months

Month/Year	I_1	I_2	I_3	I_4	O_1	O_2	O_3
Jan'11	9	10	8	8	5	6	4
Feb'11	9	10	8	8	5	6	4
March'11	9	10	8	8	5	6	4
April'11	8.5	9.5	7.5	9	5	6	4
May'11	7	9.5	7.5	8	5	6	4
June'11	7	9.5	7.5	8	5	6	4
July'11	6	9.5	7.5	8	4.5	6	4
Aug'11	6	9	7	8	4.5	6	4
Sept'11	6	9	7	8	4.5	6	4
Oct'11	6	9	7	8	4.5	6	4
Nov'11	6	9	7	8	4.5	5.5	4
Dec'11	6	9	7	8	4.5	5.5	4
Jan'12	6	9	7	8	4.5	5.5	4
Feb'12	6	9	7	8	4.5	5.5	4
March'12	6	9	7	8	4.5	5.5	4
April'12	6	8.5	7	7	4	5	4
May'12	5.5	8.5	7	7	4.5	5	3.5
June'12	5.5	8.5	6	7	4.5	5	4
July'12	5.5	8.5	6	7	4.5	5	4
Aug'12	5.5	8.5	6	7	4.5	5	4
Sept'12	5	8	6	7	4	5	4
Oct'12	5	8	6	7	4	5	4
Nov'12	5	8	6	7	4	5	4
Dec'12	5	8	6	7	4	4.5	4
Jan'13	5	7.5	6	7	4	4.5	3.5
Feb'13	5	7	6	7	4	4	3
March'13	5	6	5	7	4	4	3

Table 4.3 continued

Month/Year	I_1	I_2	I_3	I_4	O_1	O_2	O_3
April'13	5	6	5	7	4	4	3
May'13	4	5.5	4.5	7	3.5	4	3
June'13	4	5	4	7	3.5	4	3
July'13	4	5	4	6	3.5	4	3
Aug'13	4	4.5	3.5	6	3.5	4	3
Sept'13	4	4.5	3.5	4.5	3.5	4	3
Oct'13	4	5	3.5	4.5	3.5	4	3
Nov'13	4	4.5	3.5	4.5	3.5	3.5	3
Dec'13	4	4.5	3.5	3.5	3.5	3.5	3
Jan'14	4	4	3	3	3.5	3.5	3
Feb'14	4	4	3	3	3.5	3.5	3
March'14	4	4	2.5	2.5	3.5	3.5	3
April'14	4	4	2.5	2.5	3	3.5	3
May'14	4	4	2.5	2.5	3	3.5	2.5
June'14	4	3.5	2.5	2.5	3	3.5	2.5
July'14	3.5	3.5	2.5	2.5	3	3.5	2.5
Aug'14	3.5	3.5	2.5	2.5	3	3.5	2.5
Sept'14	3.5	3.5	2.5	2.5	3	3.5	2.5
Oct'14	3.5	3.5	2.5	2.5	3	3	2
Nov'14	3.5	3.5	2.5	2.5	3	3	2
Dec'14	3.5	3.5	2.5	2.5	3	3	2

Table 4.4 Result by rank

No.	DMU	Score	Rank
1	Jan'11	0.666667	46
2	feb'11	0.666667	46
3	march'11	0.666667	46
4	april'11	0.705882	45
5	may'11	0.857143	42
6	june'11	0.857143	42
7	july'11	1	1
8	aug'11	1	1
9	sept'11	1	1
10	oct'11	1	1
11	nov'11	0.916667	34
12	dec'11	0.916667	34
13	Jan'12	0.916667	34
14	feb'12	0.916667	34
15	march'12	0.916667	34
16	april'12	0.854545	44
17	may'12	0.935065	32
18	june'12	0.954545	29
19	july'12	0.954545	29
20	aug'12	0.954545	29
21	sept'12	1	1
22	oct'12	1	1

Table 4.4 continued

No.	DMU	Score	Rank
23	nov'12	1	1
24	dec'12	1	1
25	Jan'13	0.925	33
26	feb'13	0.914286	39
27	march'13	0.914286	39
28	april'13	0.914286	39
29	may'13	1	1
30	june'13	1	1
31	july'13	1	1
32	aug'13	1	1
33	sept'13	1	1
34	oct'13	1	1
35	nov'13	1	1
36	dec'13	1	1
37	Jan'14	1	1
38	feb'14	1	1
39	march'14	1	1
40	april'14	1	1
41	may'14	1	1
42	june'14	1	1
43	july'14	1	1
44	aug'14	1	1
45	sept'14	1	1
46	oct'14	0.979592	26
47	nov'14	0.979592	26
48	dec'14	0.979592	26

From Table 4.3, the time consume for each input and output reduces along four years since SMED is applied in the production line. The result is shown in ranking in Table 4.4 as explained for Table 4.2, the rank is important to show the position of each DMUs as it defined number 1 as the best efficiency. Figure 4.2 shows the graph of efficiency of each DMU in detailed for four years.

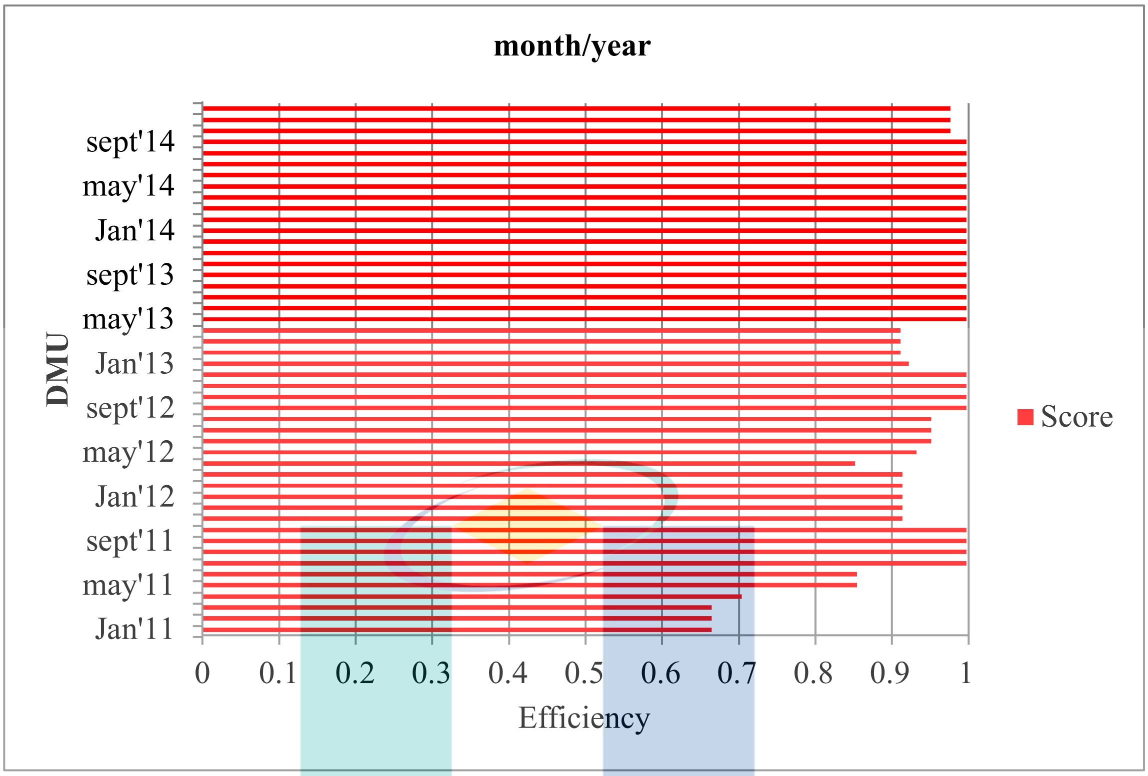

Figure 4.2 Efficiency of SMED by month

4.2 Fair Distribution Calculation using Shapley Value

In this calculation, the setup time for internal and setup time for external is calculate by using Shapley Value to identify how the distribution of time occurred. As mention earlier in chapter 2, this method create a permutation by coalition between contributor and player. The months is represented as the contributor while *P1, P2, P3, P4* are for internal activities are treated as player and *P5, P6, P7* are for external activities. Sum(I) and Sum(O) is the total time of each internal activity and external activity shown in APPENDIX B and APPENDIX C.

4.2.1 Fair Distribution Calculation using Shapley Value for Internal Activities

From equation (2) in subtopic 2.3, the normalized value will be obtained shown in APPENDIX D, where the *w* is the weight of the contributor. From APPENDIX D, all coalition's value will be enumerated. For example, the value of coalition {P1, P2} for Jan'11 is 0.257143 + 0.28571. Coalition of all players for internal activities which is P1, P2, P3, P4 will be shown in APPENDIX F and APPENDIX G. The combination of players P1, P2, P3 and P4 will created 24 permutations shown in APPENDIX I.

The average of the marginal contribution of the player was respectively taken and this average is describe as the Shapley Value shown in Table 4.5. Each players of Shapley Value then is divided with highest value of Shapley value to obtain a score for each player. The result is shown in Figure 4.4 for internal activities.

Table 4.5 Shapley Value for internal activity

Contributor / Player	P1	P2	P3	P4
Shapley Value	0.247226	0.2788731	0.2138066	0.2598781
SMED (the whole time)	248.5	324	249	286

The Figure 4.3 show the setup time for internal activities which represents as;

P1: Removing the die

P2: Setting the die

P3: Parameter setting by workers

P4: Quality confirmation by QAQC

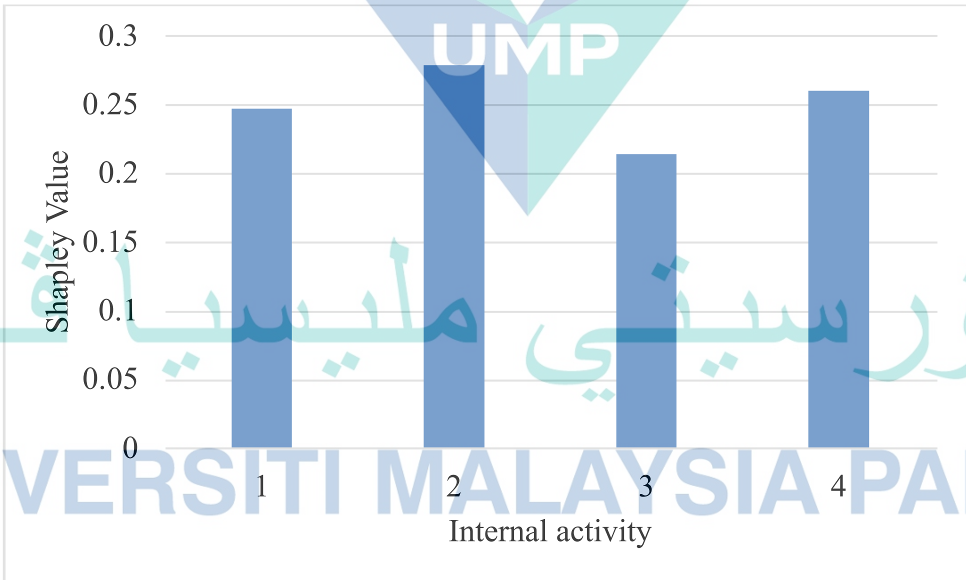

Figure 4.3 Fair distribution among internal activities

After efficiency measurement, internal activities are evaluated to determine the contribution of each activity to the production time. In Figure 4.3, shows the graph of Shapley Value of internal activities. The activity 3 which is parameter setting by workers contribute less among other activities during internal setup. This activity is done by workers which is different from removing the die and setting the die was completed by the machine. Thus, human behaviour have effected the changeover process which time for complete cycle is not constant and changes depend on how workers complete their activity.

4.2.2 Fair Distribution Calculation using Shapley Value for External Activities

From equation (2) in subtopic 2.3, the normalized value will be obtained shown in APPENDIX E, where the *w* is the weight of the contributor. From APPENDIX E, all coalition's value will be enumerated. For example, the value of coalition {*P4, P5*} for Jan'11 is 0.257143 + 0.28571. Coalition of all players for external activities which is *P5, P6, P7* will be shown in APPENDIX H. The combination of players *P5, P6* and *P7* will created 6 permutations shown in APPENDIX J.

The average of the marginal contribution of the player was respectively taken and this average is describe as the Shapley Value shown in Table 4.6. Each players of Shapley Value then is divided with highest value of Shapley value to obtain a score for each player. The result is shown in Figure 4.4 for external activities.

Table 4.6 Shapley Value for external activity

Contibutor / **Player**	**P5**	**P6**	**P7**
Shapley Value	0.338599	0.379149	0.282252
SMED (the whole time)	190	220	162.5

The Figure 4.4 show the setup time for external activities which represents as;

P5: Loosen the bolt and nut of old die

P6: Transportation of new die

P7: Workers will tighten the bolt and nut (die on bolster)

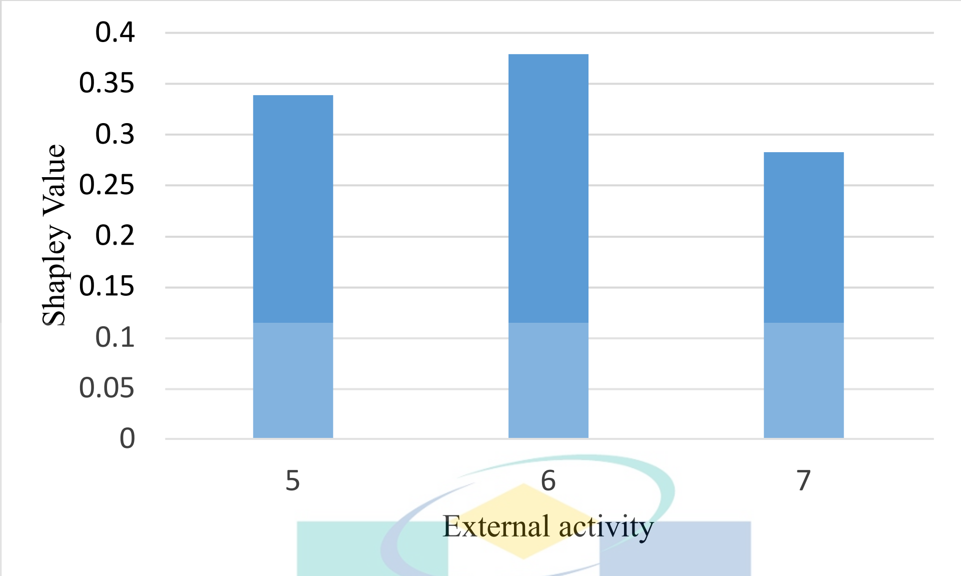

Figure 4.4 Fair distribution among external activities

Figure 4.4 shows the graph of Shapley Value for external activities where, activity 5 which is loosen the bolt and nut of old die and activity 7 which is tighten the bolt and nut (die on bolster) have least value compare to activity 6. This is because the activities are done by production workers. According to Halachmi (2005) human behaviour is one of the reason why performance measurement may not be successful. Neely et al., (1995) also mentioned that human behaviour influenced production time in many organizations.

4.3 Moving Coalition Analysis (MCA)

4.3.1 Moving Coalition Analysis (MCA) for Internal Activities

The calculation is made by using the data of input and output is shown in Table 4.7. The player for this exercise is setup time which is labelled as t_1 to t_{48}. The contributor is the activities involve in changeover die where is referred as *A1, A2, A3* and *A4* for internal part. The calculation for the 1st sub-coalition of the first part is from t_1 to t_5 for the internal part is shown in Table 4.9 to Table 4.12.

From Table 4.9, each data is divided with row-sum to normalized the sum to 1 as shown in Table 4.9. Then, all coalition's value will be enumerated. For example, the value of coalition $\{t_1, t_2\}$ for A1 is 0.211765 + 0.211765. (Refer Table 4.9). Ineach table, the underlined number shows the highest value in each column where the value will be used to find each marginal contribution.

Table 4.7 Data input for internal activities

	t_1	t_2	t_3	t_4	t_5	t_6	t_7	t_8	t_9	t_{10}	t_{11}	t_{12}	t_{13}	t_{14}	t_{15}	t_{16}
A1	9	9	9	8.5	7	7	6	6	6	6	6	6	6	6	6	6
A2	10	10	10	9.5	9.5	9.5	9.5	9	9	9	9	9	9	9	9	8.5
A3	8	8	8	7.5	7.5	7.5	7.5	7	7	7	7	7	7	7	7	7
A4	8	8	8	9	8	8	8	8	8	8	8	8	8	8	8	7
sum	35	35	35	34.5	32	32	31	30	30	30	30	30	30	30	30	28.5

	t_{17}	t_{18}	t_{19}	t_{20}	t_{21}	t_{22}	t_{23}	t_{24}	t_{25}	t_{26}	t_{27}	t_{28}	t_{29}	t_{30}	t_{31}
A1	5.5	5.5	5.5	5.5	5	5	5	5	5	5	5	5	4	4	4
A2	8.5	8.5	8.5	8.5	8	8	8	8	7.5	7	6	6	5.5	5	5
A3	7	6	6	6	6	6	6	6	6	6	5	5	4.5	4	4
A4	7	7	7	7	7	7	7	7	7	7	7	7	7	7	6
sum	28	27	27	27	26	26	26	26	25.5	25	23	23	21	20	19

	t_{32}	t_{33}	t_{34}	t_{35}	t_{36}	t_{37}	t_{38}	t_{39}	t_{40}	t_{41}	t_{42}	t_{43}	t_{44}	t_{45}	t_{46}	t_{47}	t_{48}
A1	4	4	4	4	4	4	4	4	4	4	4	3.5	3.5	3.5	3.5	3.5	3.5
A2	4.5	4.5	5	4.5	4.5	4	4	4	4	4	3.5	3.5	3.5	3.5	3.5	3.5	3.5
A3	3.5	3.5	3.5	3.5	3.5	3	3	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
A4	6	4.5	4.5	4.5	3.5	3	3	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
sum	18	16.5	17	16.5	15.5	14	14	13	13	13	12.5	12	12	12	12	12	12

Table 4.8 1st sub-coalition

	t_1	t_2	t_3	t_4	t_5	**sum**
A1	9	9	9	8.5	7	42.5
A2	10	10	10	9.5	9.5	49
A3	8	8	8	7.5	7.5	39
A4	8	8	8	9	8	41

Table 4.9 Normalized Table of 1st sub-coalition

	t_1	t_2	t_3	t_4	t_5	Sum
A1	0.211765	0.211765	0.211765	0.2	0.164706	1
A2	0.204082	0.204082	0.204082	0.193878	0.193878	1
A3	0.205128	0.205128	0.205128	0.192308	0.192308	1
A4	0.195122	0.195122	0.195122	0.219512	0.195122	1

Table 4.10 Coalition and Characteristic Function between two players

	t_1,t_2	t_1,t_3	t_1,t_4	t_1,t_5	t_2,t_3	t_2,t_4	t_2,t_5	t_3,t_4	t_3,t_5	t_4,t_5
A1	0.423529	0.423529	0.411765	0.376471	0.423529	0.411765	0.376471	0.411765	0.376471	0.364706
A2	0.408163	0.408163	0.397959	0.397959	0.408163	0.397959	0.397959	0.397959	0.397959	0.387755
A3	0.410256	0.410256	0.397436	0.397436	0.410256	0.397436	0.397436	0.397436	0.397436	0.384615
A4	0.390244	0.390244	0.414634	0.390244	0.390244	0.414634	0.390244	0.414634	0.390244	0.414634

Table 4.11 Coalition and Characteristic Function between three players

	t_1,t_2,t_3	t_1,t_2,t_4	t_1,t_2,t_5	t_1,t_3,t_4	t_1,t_3,t_5
A1	0.635294	0.623529	0.588235	0.623529	0.588235
A2	0.612245	0.602041	0.602041	0.602041	0.602041
A3	0.615385	0.602564	0.602564	0.602564	0.602564
A4	0.585366	0.609756	0.585366	0.609756	0.585366

	t_1,t_4,t_5	t_2,t_3,t_4	t_2,t_3,t_5	t_2,t_4,t_5	t_3,t_4,t_5
A1	0.576471	0.623529	0.588235	0.576471	0.576471
A2	0.591837	0.602041	0.602041	0.591837	0.591837
A3	0.589744	0.602564	0.602564	0.589744	0.589744
A4	0.609756	0.609756	0.585366	0.609756	0.609756

Table 4.12 Coalition and Characteristic Function between four players

	t_1,t_2,t_3,t_4	t_1,t_2,t_3,t_5	t_1,t_2,t_4,t_5	t_1,t_3,t_4,t_5	t_2,t_3,t_4,t_5
A1	0.835294	0.8	0.788235	0.788235	0.788235
A2	0.806122	0.806122	0.795918	0.795918	0.795918
A3	0.807692	0.807692	0.794872	0.794872	0.794872
A4	0.804878	0.780488	0.804878	0.804878	0.804878

Player t_1, t_2, t_3, t_4 and t_5 will created 120 different permutation as shown in APPENDIX K for first sub-coalition. In permutation t_1, t_2, t_3, t_4, t_5 player t_1 is the first comer to the coalition, follows by player t_2, then t_3, t_4, and finally player t_5. Thus, from

Table 4.9 to Table 4.12, marginal contribution of each player to coalition can be evaluated as below;

t_5's marginal contribution is;

c({t_1, t_2, t_3, t_4, t_5}) - c({t_1, t_2, t_3, t_4}) = 1 – 0.835294 = 0.164706

t_4's marginal contribution is;

c({t_1, t_2, t_3, t_4}) - c({t_1, t_2, t_3}) = 0.835294 - 0.635294 = 0.2

t_3's marginal contribution is;

c({t_1, t_2, t_3}) - c({t_1, t_2}) = 0.635294 - 0.423529 = 0.211765

t_2's marginal contribution is;

c({t_1, t_2}) - c({t_1}) = 0.423529 - 0.211765 = 0.211764

Lastly, t_1's marginal contribution is

c({t_1}) = 0.211765

The same calculation then was repeated for the other permutation will create 44 sub-coalition's average of the marginal contribution of each players. The results are shown in APPENDIX L. From the 44 sub-coalitions, a graph is drawn to show the trends on how the fair distribution based on time sequence. Then a graph is drawn in Figure 4.5 to show the average Shapley Value for the internal activities in changeover die.

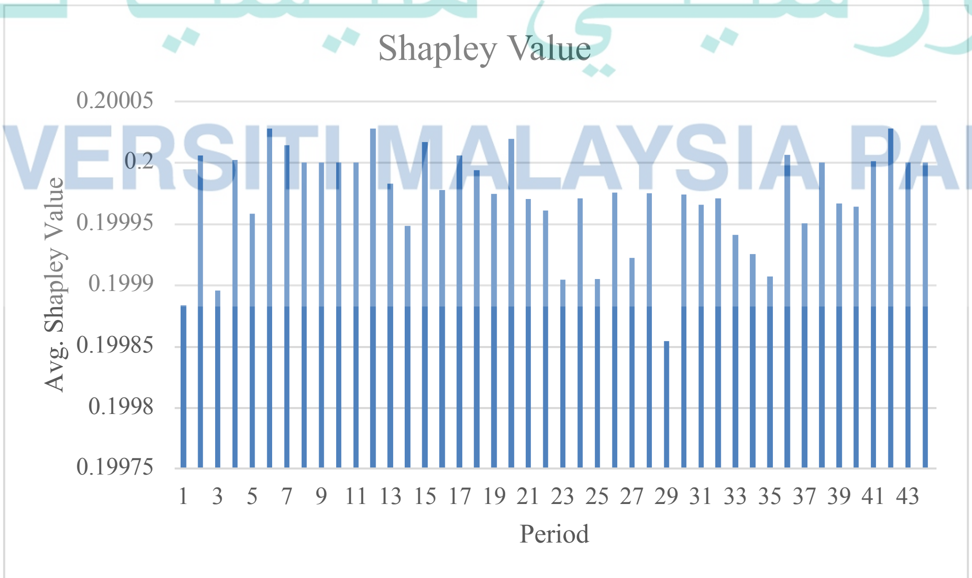

Figure 4.5 Average Shapley Value for internal activity

4.3.2 Moving Coalition Analysis (MCA) for External Activities

The calculation is made by using the data of input and output is shown in Table 4.13. The player for this exercise is setup time which is labelled as t_1 to t_{48} . The contributor is the activities involve in changeover die where is referred as A5, A6, and A7 for external part. The calculation for the 1st sub-coalition of the first part is from t_1 to t_5 for the internal part is shown in Table 4.14 to Table 4.18.

Table 4.13 Data input for external activities.

	t_1	t_2	t_3	t_4	t_5	t_6	t_7	t_8	t_9	t_{10}	t_{11}	t_{12}	t_{13}	t_{14}	t_{15}	t_{16}
A1	9	9	9	8.5	7	7	6	6	6	6	6	6	6	6	6	6
A2	10	10	10	9.5	9.5	9.5	9.5	9	9	9	9	9	9	9	9	8.5
A3	8	8	8	7.5	7.5	7.5	7.5	7	7	7	7	7	7	7	7	7
A4	8	8	8	9	8	8	8	8	8	8	8	8	8	8	8	7
sum	35	35	35	34.5	32	32	31	30	30	30	30	30	30	30	30	28.5

	t_{17}	t_{18}	t_{19}	t_{20}	t_{21}	t_{22}	t_{23}	t_{24}	t_{25}	t_{26}	t_{27}	t_{28}	t_{29}	t_{30}	t_{31}	t_{32}
A1	5.5	5.5	5.5	5.5	5	5	5	5	5	5	5	5	4	4	4	4
A2	8.5	8.5	8.5	8.5	8	8	8	8	7.5	7	6	6	5.5	5	5	4.5
A3	7	6	6	6	6	6	6	6	6	6	5	5	4.5	4	4	3.5
A4	7	7	7	7	7	7	7	7	7	7	7	7	7	7	6	6
sum	28	27	27	27	26	26	26	26	25.5	25	23	23	21	20	19	18

	t_{33}	t_{34}	t_{35}	t_{36}	t_{37}	t_{38}	t_{39}	t_{40}	t_{41}	t_{42}	t_{43}	t_{44}	t_{45}	t_{46}	t_{47}	t_{48}
A1	4	4	4	4	4	4	4	4	4	4	3.5	3.5	3.5	3.5	3.5	3.5
A2	4.5	5	4.5	4.5	4	4	4	4	4	3.5	3.5	3.5	3.5	3.5	3.5	3.5
A3	3.5	3.5	3.5	3.5	3	3	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
A4	4.5	4.5	4.5	3.5	3	3	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
sum	16.5	17	16.5	15.5	14	14	13	13	13	12.5	12	12	12	12	12	12

Table 4.14 1st sub-coalition

	t_1	t_2	t_3	t_4	t_5	Sum
A5	5	5	5	5	5	25
A6	6	6	6	6	6	30
A7	4	4	4	4	4	20

Table 4.15 Normalized Table for 1st sub-coalition

	t_1	t_2	t_3	t_4	t_5	Sum
A5	0.2	0.2	0.2	0.2	0.2	1
A6	0.2	0.2	0.2	0.2	0.2	1
A7	0.2	0.2	0.2	0.2	0.2	1

From Table 4.15, each data is divided with row-sum to normalized the sum to 1 as shown in Table 4.15. Then, all coalition's value will be enumerated. For example, the value of coalition $\{t_1, t_2\}$ for A1 is 0.2 + 0.2. (Refer Table 4.15). The highest value from each column is underlined where it will be used to find each marginal contribution.

Table 4.16 Coalition and Characteristic Function between two player

	t_1,t_2	t_1,t_3	t_1,t_4	t_1,t_5	t_2,t_3	t_2,t_4	t_2,t_5	t_3,t_4	t_3,t_5	t_4,t_5
A5	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
A6	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
A7	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4

Table 4.17 Coalition and Characteristic Function between three player

	t_1,t_2,t_3	t_1,t_2,t_4	t_1,t_2,t_5	t_1,t_3,t_4	t_1,t_3,t_5	t_1,t_4,t_5	t_2,t_3,t_4	t_2,t_3,t_5	t_2,t_4,t_5	t_3,t_4,t_5
A1	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
A2	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
A3	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6

Table 4.18 Coalition and Characteristic Function between four player

	t_1,t_2,t_3,t_4	t_1,t_2,t_3,t_5	t_1,t_2,t_4,t_5	t_1,t_3,t_4,t_5	t_2,t_3,t_4,t_5
A1	0.8	0.8	0.8	0.8	0.8
A2	0.8	0.8	0.8	0.8	0.8
A3	0.8	0.8	0.8	0.8	0.8

Player t_1, t_2, t_3, t_4 and t_5 will created 120 different permutation as shown in APPENDIX K for first sub-coalition. In permutation t_1, t_2, t_3, t_4, t_5 player t_1 is the first comer to the coalition, follows by player t_2, then t_3, t_4, and finally player t_5. Thus, from Table 4.14 to Table 4.18, marginal contribution of each player to coalition can be evaluated as below;

t_5's marginal contribution is;

$c(\{t_1, t_2, t_3, t_4, t_5\}) - c(\{t_1, t_2, t_3, t_4\}) = 1 – 0.8 = 0.1$

t_4's marginal contribution is;

$c(\{t_1, t_2, t_3, t_4\}) - c(\{t_1, t_2, t_3\}) = 0.8 - 0.6 = 0.2$

t_3's marginal contribution is;

$c(\{t_1, t_2, t_3\}) - c(\{t_1, t_2\}) = 0.6 - 0.4 = 0.2$

t_2's marginal contribution is;

$c(\{t_1, t_2\}) - c(\{t_1\}) = 0.4 - 0.2 = 0.2$

Lastly, t_1's marginal contribution is

$c(\{t_1\}) = 0.2$

The same calculation then was repeated for the other permutation will create 44 sub-coalition's average of the marginal contribution of each players. The results are shown in APPENDIX M. From the 44 sub-coalitions, a graph is drawn to show the trends on how the fair distribution based on time sequence. Then a graph is drawn in Figure 4.6 to show the average Shapley Value for the external activities in changeover die.

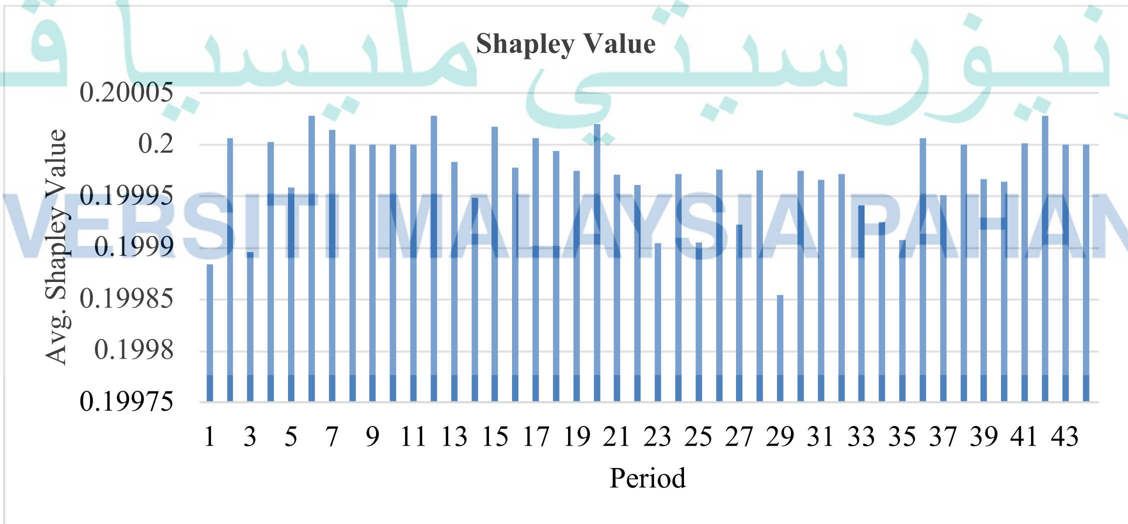

Figure 4.6 Average Shapley Value for external activity

From the Figure 4.5 and Figure 4.6, the graph show a trend of how the reduction time process happen along SMED implementation. Both graph shows the fluctuation because the time reduction occur along three years shows some improvement in time while some improvement reduces the average SOB. The engineer in this company that do some rearrangement have affected the time taken for each activities for internal and external. Thus, the whole changeover process is affected and some changes give good result while some not.

4.4 Transpose Moving Coalition Analysis (T-MCA)

4.4.1 Transpose Moving Coalition Analysis (T-MCA) for Internal Activities

For Transpose Moving Coalition Analysis (T-MCA), the steps of calculation is similar as MCA but transpose the position of player and contributor. In MCA, time and activity are in the row and the column, respectively. However, in T-MCA, activity are located in the column and activity in the row. Then the sub-coalitions is created in vertical as shown in Table 4.14. Now, the evaluation is on how the contribution of activity affected the SMED efficiency because the player in this exercise is activity.

Table 4.19 Normalized value for 1st sub-coalition

	A1	A2	A3	A4	sum
t_1	0.257143	0.285714	0.228571	0.228571	1
t_2	0.257143	0.285714	0.228571	0.228571	1
t_3	0.257143	0.285714	0.228571	0.228571	1
t_4	0.246377	0.275362	0.217391	0.26087	1
t_5	0.21875	0.296875	0.234375	0.25	1

Table 4.20 Coalition and Characteristic Function between two players

	1,2	1,3	1,4	2,3	2,4	3,4
t_1	0.542857	0.485714	0.485714	0.514286	0.514286	0.457143
t_2	0.542857	0.485714	0.485714	0.514286	0.514286	0.457143
t_3	0.542857	0.485714	0.485714	0.514286	0.514286	0.457143
t_4	0.521739	0.463768	0.507246	0.492754	0.536232	0.478261
t_5	0.515625	0.453125	0.46875	0.53125	0.546875	0.484375

Table 4.21 Coalition and Characteristic Function between three players

	1,2,3	1,2,4	1,3,4	2,3,4
t_1	0.771429	0.771429	0.714286	0.742857
t_2	0.771429	0.771429	0.714286	0.742857
t_3	0.771429	0.771429	0.714286	0.742857
t_4	0.73913	0.782609	0.724638	0.753623
t_5	0.75	0.765625	0.703125	0.78125

Table 4.22 Transpose Coalition for 1st sub-coaltion

	A1	A2	A3	A4
t_1, t_2, t_3, t_4	0.25714	0.28571	0.22857	0.22857
t_1, t_2, t_4, t_3	0.25714	0.28571	0.21739	0.23975
t_1, t_3, t_2, t_4	0.25714	0.28571	0.22857	0.22857
t_1, t_3, t_4, t_2	0.25714	0.27536	0.22857	0.23892
t_1, t_4, t_3, t_2	0.25714	0.27536	0.21739	0.25010
t_1, t_4, t_2, t_3	0.25714	0.27536	0.21739	0.25010
t_2, t_1, t_3, t_4	0.24598	0.29688	0.22857	0.22857
t_2, t_1, t_4, t_3	0.24598	0.29688	0.21739	0.23975
t_2, t_3, t_1, t_4	0.24018	0.29688	0.23438	0.22857
t_2, t_3, t_4, t_1	0.21875	0.29688	0.23438	0.25000
t_2, t_4, t_1, t_3	0.23573	0.29688	0.21739	0.25000
t_2, t_4, t_3, t_1	0.21875	0.29688	0.23438	0.25000
t_3, t_1, t_2, t_4	0.25134	0.28571	0.23438	0.22857
t_3, t_1, t_4, t_2	0.25134	0.27536	0.23438	0.23892
t_3, t_2, t_1, t_4	0.24018	0.29688	0.23438	0.22857
t_3, t_2, t_4, t_1	0.21875	0.29688	0.23438	0.25000
t_3, t_4, t_1, t_2	0.24026	0.27536	0.23438	0.25000
t_3, t_4, t_2, t_1	0.21875	0.29688	0.23438	0.25000
t_4, t_1, t_2, t_3	0.24638	0.27536	0.21739	0.26087
t_4, t_1, t_3, t_2	0.24638	0.27536	0.21739	0.26087
t_4, t_1, t_3, t_2	0.24638	0.27536	0.21739	0.26087
t_4, t_2, t_1, t_3	0.23573	0.28601	0.21739	0.26087
t_4, t_2, t_3, t_1	0.21875	0.28601	0.23438	0.26087
t_4, t_3, t_1, t_2	0.24026	0.27536	0.22351	0.26087
t_4, t_3, t_2, t_1	0.21875	0.29688	0.22351	0.26087
Sum	5.77510	6.88652	5.44418	5.89420
Mean	0.240629	0.286938	0.226841	0.245592
Sob	0.83861	1	0.790556	0.855905

1st sub-coalition is shown in Table 4.14. The same procedures as described in section 4.3 are used to obtain other sub-coalitions, normalized values (Table 4.19), coalition and characteristic function (Table 4.20 and Table 4.21), marginal contribution

(Table 4.22). The graph of the results from this exercise is plotted Figure 4.7 until Figure 4.10 for each internal activity.

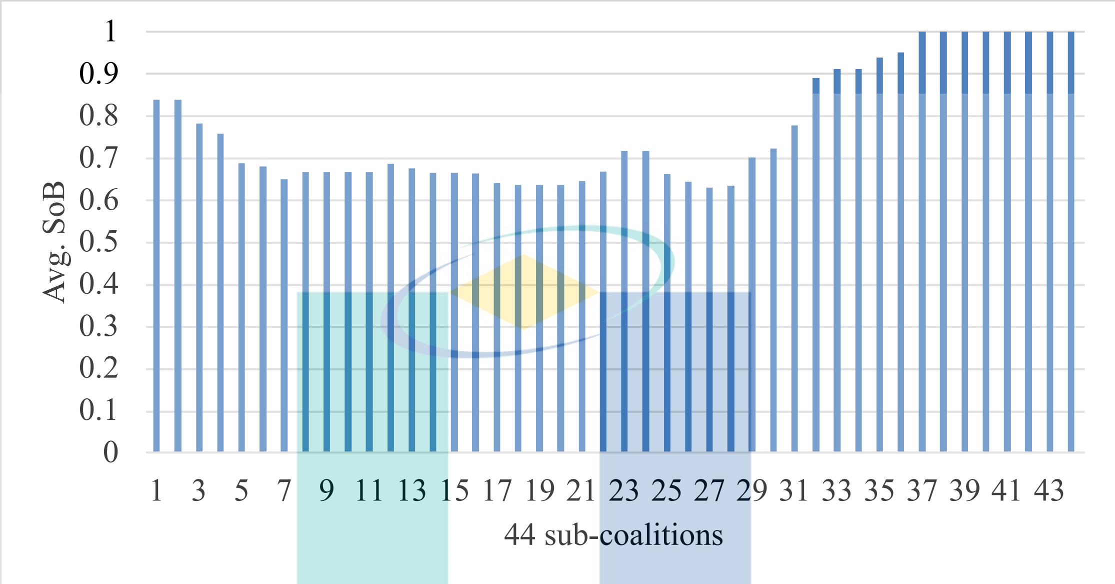

Figure 4.7 Average SOB for removing die

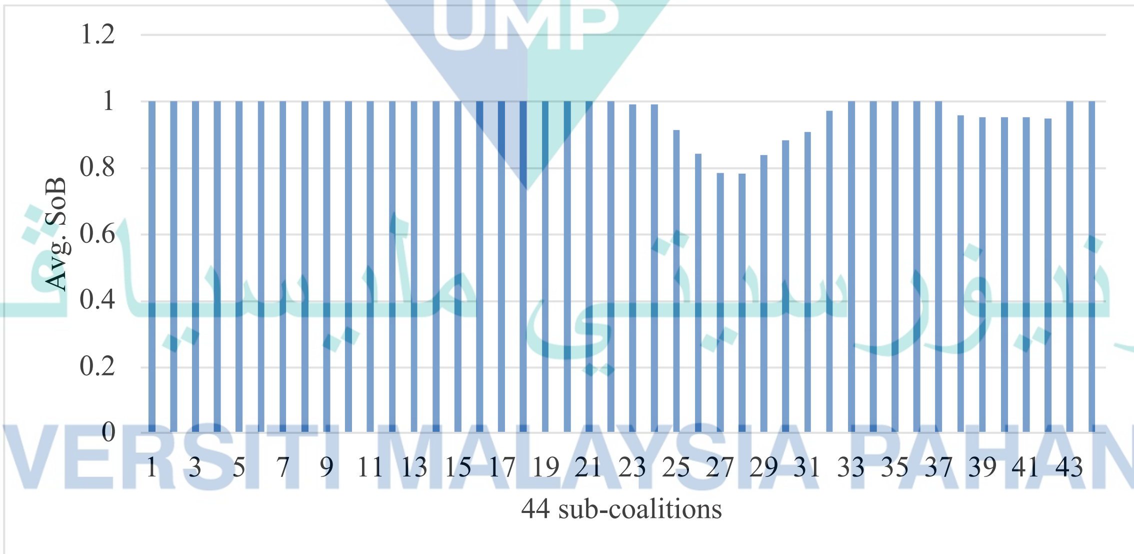

Figure 4.8 Average SOB for setting the die

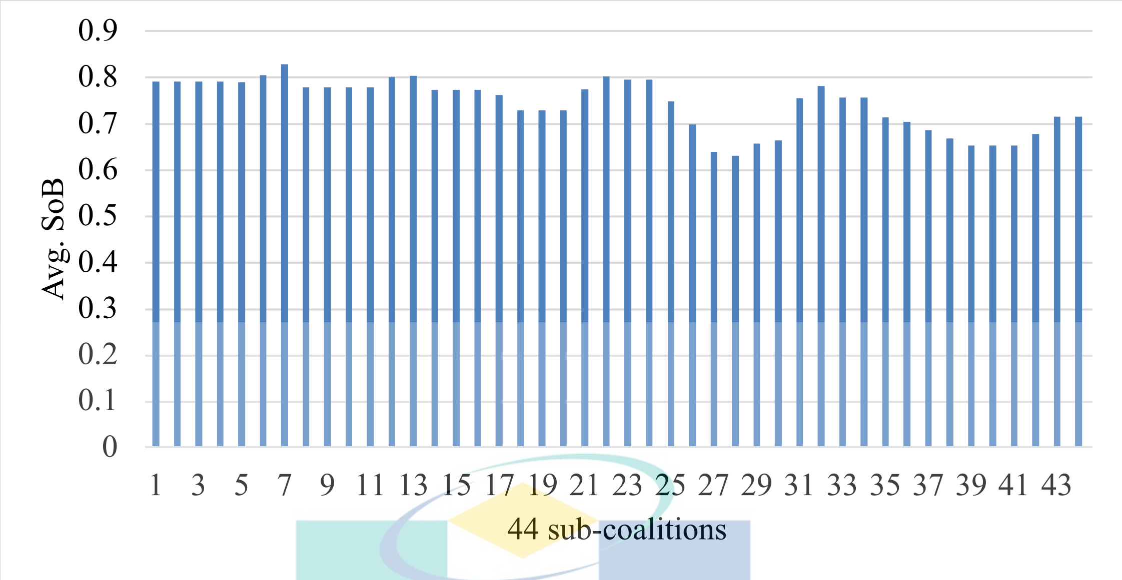

Figure 4.9 Average SOB for parameters setting by workers

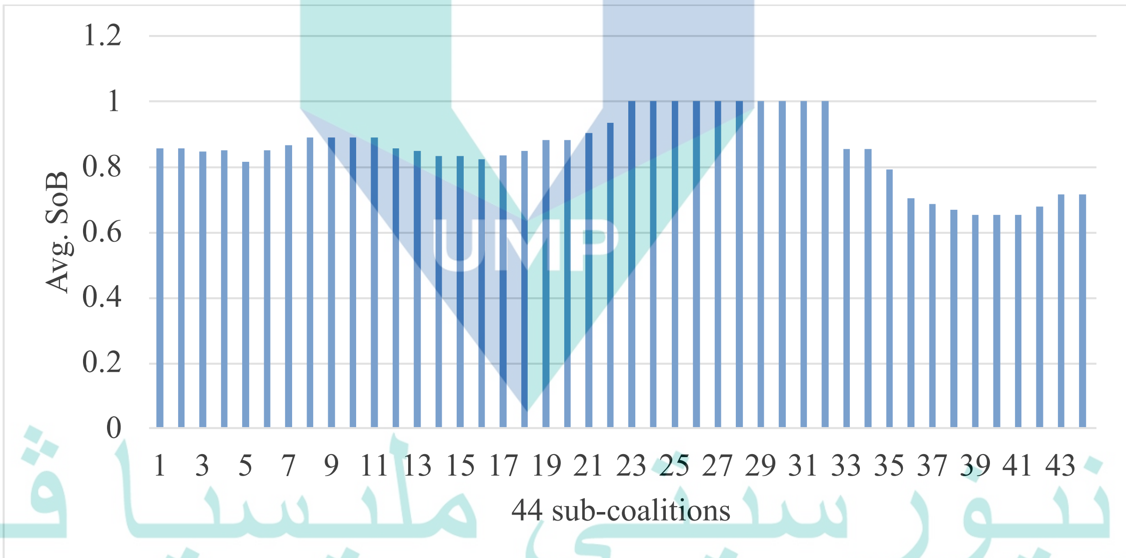

Figure 4.10 Average SOB for quality confirmation by QAQC

4.4.2 Transpose Moving Coalition Analysis (T-MCA) for External Activities

Then, for external activities the 1st sub-coalition is shown in Table 4.23. The same procedures as described in section 4.3 are used to obtain other sub-coalitions, normalized values (Table 4.23), coalition and characteristic function (Table 4.24 and Table 4.25), marginal contribution (Table 4.26). The graph of the results from this exercise is plotted Figure 4.9 until Figure 4.15 for each activity for internal and external activities.

Table 4.23 Normalized value for 1st sub-coaltion

	A5	A6	A7	sum
t_1	0.333333	0.4	0.266667	1
t_2	0.333333	0.4	0.266667	1
t_3	0.333333	0.4	0.266667	1
t_4	0.333333	0.4	0.266667	1
t_5	0.333333	0.4	0.266667	1

Table 4.24 Coalition and Characteristic Function between two players.

	A5,A6	A5,A7	A6,A7
t_1	0.733333	0.6	0.666667
t_2	0.733333	0.6	0.666667
t_3	0.733333	0.6	0.666667
t_4	0.733333	0.6	0.666667
t_5	0.733333	0.6	0.666667

Table 4.25 Transpose Coalition for 1st sub-coaltion

	A5	A6	A7
t_1, t_2, t_3	0.333333	0.4	0.266667
t_1, t_3, t_2	0.333333	0.4	0.266667
t_2, t_3, t_1	0.333333	0.4	0.266667
t_2, t_1, t_3	0.333333	0.4	0.266667
t_3, t_2, t_1	0.333333	0.4	0.266667
t_3, t_1, t_2	0.333333	0.4	0.266667
Sum	2	2.4	1.6
Mean	0.333333	0.4	0.266667
SOB	0.833333	1	0.666667

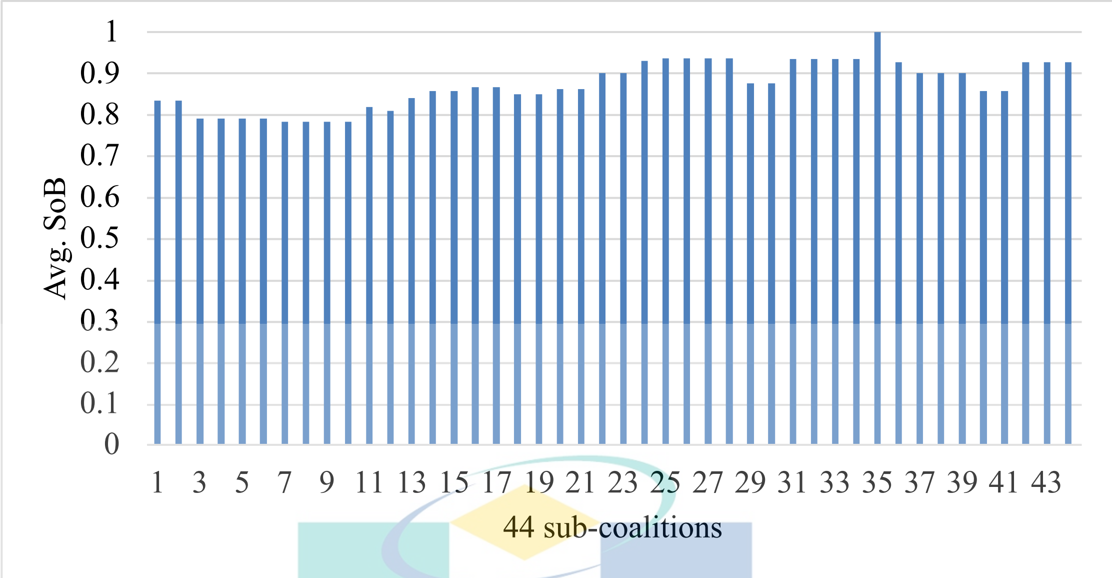

Figure 4.11 Average SOB for loosen the bolt and nut for old die

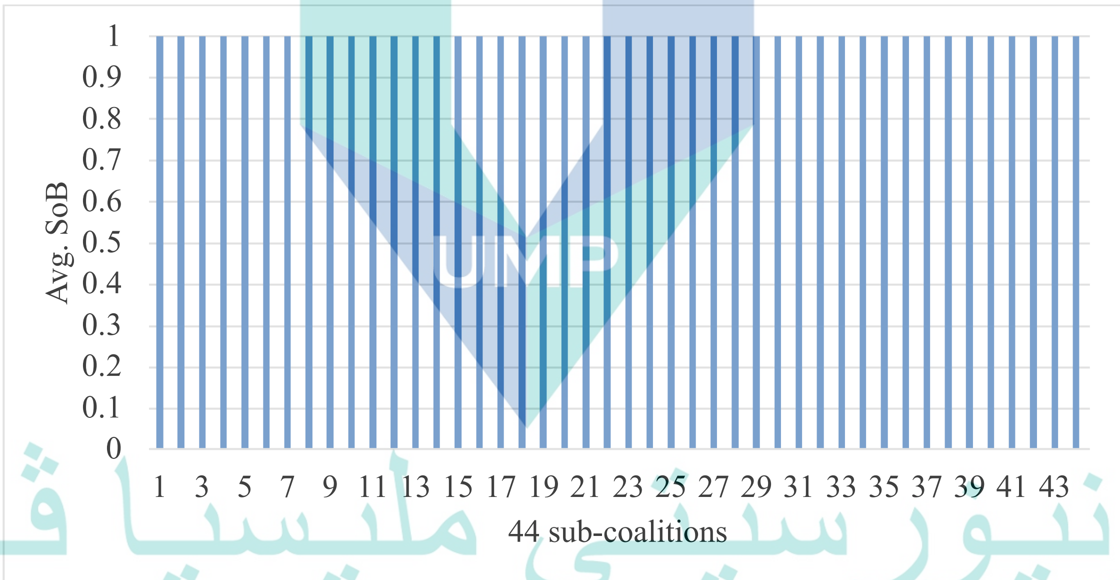

Figure 4.12 Average SOB for transportation of new die

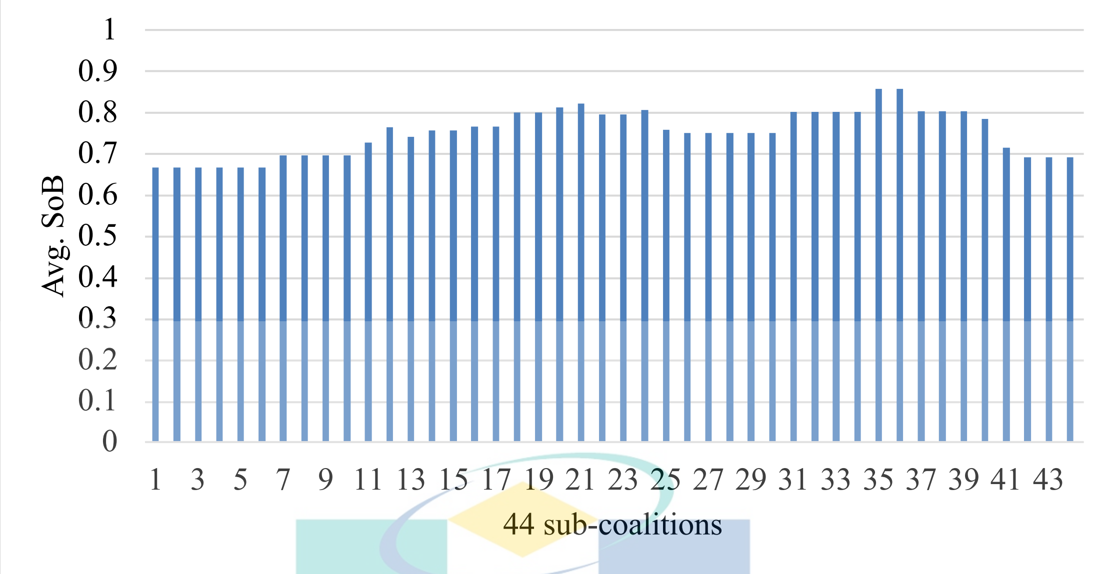

Figure 4.13 Average SOB for workers will tighten the bolt and nut (die on bolster)

From the results, the changes of graph can be seen for three years of SMED implementation. These changes were created due to the different values of marginal contributions of each player. These improvements shows which activity is most excellent in performance. From Figure 4.12, for activity in external, have a better average SoB in comparison to loosen the bolt and nut of old die and tighten the bolt and nut (die on bolster). Since this activity is done by workers, the efficiency is not constant because human behaviour have affected the time taken for a complete changeover die as mention in sub topic 4.2. As for internal activities shown in Figure 4.11 until Figure 4.13, the graph for each activity also give fluctuation results as most activity is done by human.

4.5 A Proposed Method

The measurement for this exercise is divided into 2 parts; where the DEA will measure the efficiency of SMED implemented in the production and Shapley value will evaluate the fair distribution on efficiencies that is measured. As mention in chapter 3 earlier, the Table 3.4 shows the illustrative example on how this exercise will carry on. The data of each year is divided in quartile because usually production line will collect data every three months for evaluation process. The results in Table 4.26 shows the SMED's efficiencies obtained from DEA using equation (6) in chapter 2. SMED efficiencies is treated as contributor in Shapley Value method because need to identify how efficient the contribution of DEA efficiency in each year.

Each data represent the actual value where it will divided with sum of each quartile to obtained normalized value shown in Table 4.27. From equation (1) and (5) from chapter 2, all coalitions then are enumerated to create its permutation. For example, the value of coalition {11,12} for Q1 is 0.255474 + 0.255474 shown in Table 4.28. Coalition of all players for each year for {11,12,13} is 0.510949 + 0.233577 shown in Table 4.29 below. The combination of players will created 24 permutations shown in Table 4.30. The average of the marginal contribution of the player was respectively taken and this average is describe as the Shapley Value shown in Table 4.20.

Table 4.26 Result from DEA calculation.

Quartile/Year	2011	2012	2013	2014	sum
Q1	1	1	0.914286	1	3.914286
Q2	1	1	0.967033	1	3.967033
Q3	1	1	1	1	4
Q4	1	1	1	0.979592	3.979592

Table 4.27 Normalized Value

Quartile/Year	NV11	NV12	NV13	NV14
Q1	0.255474	0.255474	0.233577	0.255474
Q2	0.252078	0.252078	0.243767	0.252078
Q3	0.25	0.25	0.25	0.25
Q4	0.251282	0.251282	0.251282	0.246154

Table 4.28 Coalition and Characters Function of two players

Quartile/Year	11,12	11,13	11,14	12,13	12,14	13,14
Q1	0.510949	0.489051	0.510949	0.489051	0.510949	0.489051
Q2	0.504155	0.495845	0.504155	0.495845	0.504155	0.495845
Q3	0.5	0.5	0.5	0.5	0.5	0.5
Q4	0.502564	0.502564	0.497436	0.502564	0.497436	0.497436

Table 4.29 Coalition and Characters Function of three players

Quartile/Year	11,12,13	11,12,14	11,13,14	12,13,14
Q1	0.744526	0.766423	0.744526	0.744526
Q2	0.747922	0.756233	0.747922	0.747922
Q3	0.75	0.75	0.75	0.75
Q4	0.753846	0.748718	0.748718	0.748718

Table 4.30 Permutation

Quartile/Year	2011	2012	2013	2014
Q1,Q2,Q3,Q4	0.255474	0.255474	0.242897	0.246154
Q1,Q2,Q4,Q3	0.255474	0.255474	0.233577	0.255474
Q1,Q3,Q2,Q4	0.255474	0.251282	0.24709	0.246154
Q1,Q3,Q4,Q2	0.255474	0.25	0.24709	0.247436
Q1,Q4,Q3,Q2	0.255474	0.25	0.239051	0.255474
Q1,Q4,Q2,Q3	0.255474	0.255474	0.233577	0.255474
Q2,Q1,Q3,Q4	0.255474	0.255474	0.242897	0.246154
Q2,Q1,Q4,Q3	0.255474	0.255474	0.233577	0.255474
Q2,Q3,Q1,Q4	0.251282	0.255474	0.24709	0.246154
Q2,Q3,Q4,Q1	0.25	0.255474	0.24709	0.247436
Q2,Q4,Q1,Q3	0.255474	0.255474	0.233577	0.255474
Q2,Q4,Q3,Q1	0.25	0.255474	0.239051	0.255474
Q3,Q1,Q2,Q4	0.251282	0.251282	0.251282	0.246154
Q3,Q1,Q4,Q2	0.251282	0.25	0.251282	0.247436
Q3,Q2,Q1,Q4	0.251282	0.251282	0.251282	0.246154
Q3,Q2,Q4,Q1	0.25	0.251282	0.251282	0.247436
Q3,Q4,Q1,Q2	0.25	0.25	0.251282	0.248718
Q3,Q4,Q2,Q1	0.25	0.25	0.251282	0.248718
Q4,Q1,Q2,Q3	0.255474	0.255474	0.233577	0.255474
Q4,Q1,Q3,Q2	0.255474	0.25	0.239051	0.255474
Q4,Q2,Q1,Q3	0.255474	0.255474	0.233577	0.255474
Q4,Q2,Q3,Q1	0.25	0.255474	0.239051	0.255474
Q4,Q3,Q1,Q2	0.25	0.25	0.244526	0.255474
Q4,Q3,Q2,Q1	0.25	0.25	0.244526	0.255474
Sum	6.070822	6.070822	5.828561	6.029796
Average	0.252951	0.252951	0.242857	0.251241
%	25.29	25.29	24.28	25.12

Final calculation for this study is the combination of DEA and Shapley Value to measure the efficiency of SMED implementation. From these combination, the result show how efficient the time reduction occur throughout four years. Table 4.30 shows the fair distribution of efficiency for each year, where the average Shaley Value defined the contribution of each each in SMED. The marginal contribution of each year shows that 2013 is least contribute among others as with the results that calculate the effectiveness of SMED using DEA also shown in Table 4.16. From this result, the efficiency of each activities can be measure to identify its contribution in SMED's improvement whether the improvements done is excellent or not.

4.6 Summary

In this chapter, two kinds of evaluation is carried out by using DEA model in measuring the effectiveness of SMED, where the year and the months are treated as DMUs. The former evaluation is to determine how the effectiveness of SMED throughout the years. While the latter measures are to identify the most efficient month in each year after improvements have been made. The result of SMED's performance based on year by year's evaluation will show the overall effectiveness of the activities while the result based on month by month will display in detailed efficiency for each year.

Shapley Value is used to measure fair distribution of internal activities and external activities in determining which activity is less or more contribute to the changeover process. The Moving Coalition Analysis (MCA) and Transpose-Moving Coalition Analysis (TMCA) is applied to observe how the performance trends of activity involved in the SMED and the time consumed changes in time series. MCA measures the time consumed for each month to complete the activities involved in SMED where the outcome of this evaluation is to determine the time direction of each month from time to time. While, T-MCA measures the time consumed for each SMED's activity in every month where this evaluation is to identify how important of each activity from time to time.

The combination method of DEA and Shapley Value is applied in identifying the contribution of each efficiency in changeover process. This combination method is used since the DEA model only can measure the efficiency of SMED, but Shapley Value will measure the contribution of each effectiveness throughout its implementation. This method measures how the efficiency of SMED's implementation in each year affected the overall activities in four years.

CHAPTER 5

CONCLUSION

5.1 Conclusion

First, the modified DEA model is used to measure the performance of SMED. This method is applied because the DEA model can handle multiple input and output which is suitable as all the parameters can be calculated simultaneously to obtain an accurate results. While Shapley Value for evaluation of SMED efficiency in order to determine its contribution to the production line. The DEA model itself does not pay attention to individual contribution of each efficiency when measuring the performance of SMED. Thus, this combination measurement technique can be used to measure how excellent the improvement done by understand the contribution of each efficiency in the changeover process. Hence, the measurement will focus on the contributor to estimate the highest or lowest performing in period rather than the performance of entire SMED activity. This answered the objective one stated in Chapter 1.

Second, the Shapley Value is applied to identify the fair distribution of each internal activity and external activity in changeover process in order to determine the contribution of each parameters. This evaluation uses a coalition between activity to determine the contribution of each activity which most contribute during the production process. This evaluation is important to the company as it can assist which activities need to be improved upon knowing the contribution of each activity in the exchange of die. The company does not have to change the whole activity to reduce the changeover time since the contribution of each activity has been calculated. Thus, the improvement could be made on specific activity rather that overall setup activities.

Third, the main objective MCA method and TMCA method is applied in this research because both methods can observe in detail the role of activity and time consume for changeover die in SMED. Both methods can identify the advantages and disadvantages of each activity or time in order to achieve its goal. Furthermore, this method will illustrate the relationship between each activity and time consume by considering the balance of combination between activity when performing the changeover die. Therefore, this detailed result can investigate the gap between contributing factor that effected to higher achievement.

5.2 Contribution to the Academic

From this research, a suitable/relevant inputs and outputs for DEA model have been proposed to measure the SMED's effectiveness of the conversion process in stamping production line. The activity involved in changeover process and the time consumed for activities are identified as parameter in determining the contribution of each activity in SMED. The same parameters is used for dynamic evaluation which focus on the trends in the time series for each periods and time series of overall activity respectively. The combination method of DEA and Shapley Value where Shapley Value is used to evaluate the DEA's efficiency in order to identify the contribution of each efficiency in changeover process.

5.3 Contribution to the Industry

This research will help the engineer to identify changes that occur, worth or not with the results of the effectiveness gained. The results will show the production line can set up high demand on time without delay and increase the product if demand is high. In addition, this conversion process can be done if the manager a have knowledge about SMED because there is some production not applying SMED correctly causing the reduction of time is very difficult. Furthermore, skills and training on employees are needed to carry out the improvement that take place to meet high demand as if the Standard Operation Procedures (SOP) changes.

5.4 Future Work

This research calculate the SMED effectiveness but the calculation will only shows the effectiveness of SMED that has happened before. Therefore, the results cannot be used as a decision in determining and planning in the future for the production efficiency.

A proper planning is important for a company to maximize its productivity because longer changeover process contributes to a longer production time in a metal stamping production line. Therefore, forecasting could help the company to obtain a better result to improve the time consumed needed for each activity, number of manpower and may include also the cost consumed. This would help the company to eliminate the unnecessary activity that contribute to longer changeover process. Therefore, a framework needs to be develop to ensure that the company can forecast the effectiveness of converting process in SMED.

REFERENCES

Alves, A. S. and Tenera, A., (2009) Improving SMED in the Automotive Industry: A case study, Production and Operations Management Society 20th Annual conference Orlando, Florida U.S.

Azizi, A. (2015). Manoharan, T.,"Designing a Future Value Stream Mapping to Reduce Lead Time Using SMED-A Case Study," Procedia Manuf., vol. 2, 153-158.

Azzone G., Masella C., Bertele U., (1991), Design of performance measures for time-based companies, International Journal of Operations and Production Management 11 (3) 77–85.

Bajpai, J. D. (2014). SMED (Single-Minute Exchange of Die) Methodology in Garment manufacturing Industry : Case study in reducing Style Change over Time, (Aimtdr), 1–7.

Bevilacqua, M., F. E. Ciarapica, I. De Sanctis, G. Mazzuto, and C. Paciarotti. (2015). "A Changeover Time Reduction through an Integration of Lean Practices: A Case Study from Pharmaceutical Sector." Assembly Automation 35 (1): 22–34. doi:10.1108/AA-05-2014-035.

Brito, A. M., Ramos, A. L., Carneiro, P., & Gonçalves, M. A. (2017). Combining SMED methodology and ergonomics for reduction of setup in a turning production area, Procedia Manufacturing 13, 1112-1119.

Cakmakci M. (2009), "Process Improvement: Performance analysis of the setup time reduction SMED in the automobile industry", International Journal of Advanced Manufacturing Technology, 2009; 41; 168-179

Charnes, A., Cooper, W. W., and Rhodes, E. (1978), European Journal of Operation Research 2,pp.429-444.

Che Ani, M. N. and Shafei, M.S.S., (2014) The effectiveness of the single minute exchange of die (SMED) technique for the productivity improvement, in Applied mechanics and materials. p. 1144–1148

Costa, E., Sousa, R., Bragança, S., & Alves, A. (2013), An Industrial Application Of The Smed Methodology And Other Lean Production Tools. Integrity, Reliability and Failure of Mechanical System.

Costa, E., Sousa, R., Bragança, S., & Alves, A. (2013), Benefits from a SMED Application in a Punching Machine, Engineering and Technology International Journal of Mechanical, Aerospace, Industrial, Mechatronic and Manufacturing Engineering, 7(5) 1-6.

Desai, M. (2015). Set Up Change Time Optimization Using Single Minute Exchange of Die (SMED) Methodology, 2(1).

Desai, M. S., & Warkhedkar, R. M., (2011), Productivity Enhancement by Reducing Adjustment Time and Setup Change*, International Journal of Mechanical and Industrial Engineering*, 1(1), pp. 7-42.

Frigo, M. (2003), "Performance measures that drive the goal Tenets of strategy", Strategic Finance, Vol. 85, pp. 9-13.

Folan, P., & Browne, J. (2005). A review of performance measurement: Towards performance management. Computers in Industry, 56(7), 663–680.

Gabahne, L. D., Gupta, M. M., & Zanwar, M. D. (2014). Overall equipment effectiveness improvement: A case of injection molding machine. *The International Journal Of Engineering And Science (IJES)*, *3*(8), 01-10.

Gilmore, M., Smith, D. (1990). Setup reduction in pharmaceutical manufacturing: an action research study. *International Journal of Production Research*, 16(3), 4-17

Goubergen D, Landeghem H., (2002), Rules for integrating fast changeover capabilities into new equipment design. *Robotics and Computer Integrated Manufacturing*, 18, p. 205-214.

Halachmi, A. (2005). "Performance measurement: test the water before you dive in." *International Review of Administrative Sciences* 71(2): 255-266.

Holweg, M., (2006). The genealogy of lean production. *Journal of Operations Management,* 25, 420-437.

Isme, M. E., & Assaf, R. (2012), Systems Performance Improvement Using the Single Minute Exchange of Die (SMED) Methodology in an Aluminum Profiles Extrusion Production System, *The 1 st International Conference on Industrial.*

Karam, A. A., Liviu, M., Cristina, V., & Radu, H. (2018). The contribution of lean manufacturing tools to changeover time decrease in the pharmaceutical industry. A SMED project. *Procedia Manufacturing*, *22*, 886-892.

Kaplan R., Norton D., (1992), The balanced scorecard—measures that drive performance, Harvard Business Review (January–Feb- ruary) 70 (1) pp. 71–79

Kaydos W., (1991) Measuring, Managing and Maximising .Performance, Productivity Press, Cambridge, MA, USA.

Kayis.B and Kara.S, (2007), Set-Up Reduction in Injection Molding Process: A Case Study in Packaging Industry, *4th International Conference and Exhibition on Design and Production of Machines and Dies/Molds, Cesme*, Turkey.

Krajewski, L., & Ritzman, L. (2007). Operations management: Processes and value chains. Upper Saddle River, NJ: Pearson Education, Inc.

Kumar, V., & Bajaj, A. (2015). The Implementation of Single Minute Exchange of Die with 5 ' S in Machining Processes for reduction of Setup Time. *International Journal on Recent Technologies in Mechanical and Electrical Engineering*, 2(2), 32–39.

Kumaresan & Saman, (2011) Integration of SMED and Triz in improving productivity at semiconductor industry. *Journal Mechanical*, v33. 40-55.

Lockamy III, (1991), A., a study of operational and strategic performance measurement systems in selected world class manufacturing firms: an examination of linkages for competitive advantage, Ph.D. Thesis, University of Georgia.

Malone, T. and Sinnett, W. (2005), "Performance management", Financial Executive, Vol. 21, pp. 60-3.

Mansor, M. A., Ismail, A. R., Razak, L. T., & Razak, L. T. (2014). Implementation of Single Minutes of Exchange Die (SMED) in Malaysia Metal Stamping Industry : A Case Study.

Marchwinski, C., & Shook, J. (2003). Lean lexicon: A graphical glossary for lean thinkers. Brookline, MA: Lean Enterprise Institute.

Melton, T. (2005). The benefits of lean manufacturing what lean thinking has to offer the process industries. Chemical Engineering Research and Design, 83(A6), 662–673

Michels, B. (2007). Application of Shingo's Single Minute Exchange of Dies (SMED) Methodology to Punch Press Changeover Times at Krueger International, 5th ed., American Psychological Association, Washington, DC.

Min, W., Pheng, L. S. (2007). Modeling just-in-time pur- chasing in the ready mixed concrete industry. International Journal of Production Economics, 107, 190–201.

Mistry, P. J and Desai, M. (2015). Set Up Change Time Optimization Using Single Minute Exchange of Die (SMED) Methodology, *2*(1).

Mohamed Esa, M., Abdul Rahman, N. A., & Jamaludin, M. (2015). Reducing High Setup Time in Assembly Line: A Case Study of Automotive Manufacturing Company in Malaysia. Procedia - Social and Behavioral Sciences, 211, 215–220.

Moreira, A. C., & Pais, G. C. S. (2011). Single minute exchange of die. A case study implementation, 6(1), 129–146.

Moxham C. and Greatbanks R., (2001), Prerequisites for the implementation of the SMED methodology: A study in a textile processing environment, International Journal of Quality & Reliability Management, 18 (4); 404-414.

Neely, A. (1999), "The performance measurement revolution", International Journal of Operations & Production Management, Vol. 19, pp. 205-28.

Neely, A., Gregory, M., Platts, K., Franco-santos, M., Kennerley, M., Micheli, P., Platts, K. (1995). A literature review and research agenda, Inter- national Journal of Operations and Production Management 15 (4) (1995) 80–116.

Patel S, Shaw P. and Dale B.G., (2001), Set-up time reduction and Mistake proofing methods: A study of application in a small company, *Business Process Management Journal*, 2001; 7 (1); 65-75.

Rahul.R.Joshi and Prof.G.R.Naik, (2012) "Application of SMED Methodology – A Case Study in Small Scale Industry", *International Journal of Scientific and Research Publication*, 6(8); 1-4

Robinson, A. (1990), Modern Approaches to Manufacturing Improvement: The Shingo System, Productivity Press, Portland, OR.

Rouse P., Putterill M., (2003), An integral framework for performance measurement, Management Decision 41 (8) 791– 805

Roth, A. E., (1988), The Shapley Value: Essays in honour of Lyold S. Shapley, Cambridge University Press, ISBN 0-521-36177-X

Roth, A. E. (1977). The Shapley value as a von Neumann-Morgenstern utility. *Econometrica: Journal of the Econometric Society*, 657-664.

Rosa, C., Silva, F. J. G., Ferreira, L. P., & Campilho, R. (2017). SMED methodology: The reduction of setup times for Steel Wire-Rope assembly lines in the automotive industry. *Procedia Manufacturing*, *13*, 1034-1042.

Rubrich L, and Watson M. (2004), "Implementing world class manufacturing, Fort Wayne, IN: WCM Associates.

Sherman, H. D., & Zhu, J. (2006). *Service productivity management: improving service performance using Data Envelopment Analysis (DEA)*. Springer science & business media.

Shingo, S. (1985), A Revolution in Manufacturing: The SMED System, Productivity Press, Cambridge, MA

Shingo, S., (1981) Study of Toyota Production System, p 70

Shingo, S., (1989), A study of the Toyota Production System, Productivity Press, p 47.

Simões, A., & Tenera, A. (2010). Improving setup time in a Press Line–Application of the SMED methodology. *IFAC Proceedings Volumes*, *43*(17), 297-302.

Trovinger, S.C. and Bohn, R.E. (2005), "Setup time reduction for electronics assembly: combining simple (SMED) and IT-based methods", *Production and Operations Management*, Vol. 14 No. 2, pp. 205-217

Ulutas, B., (2011), An application of SMED Methodology, World Academy of Science, Engineering and Technology; 79;100-103

Ulutas, B., (2011), An application of SMED Methodology, Engineering and Technology International Journal of Mechanical, Aerospace, Industrial, Mechatronic and Manufacturing Engineering, 5(7) 1194-1197.

Vardeman, S. B, (1987), "The Impact of Dr. Shingo on Modern Manufacturing Practices". IE 361. Utah State University.

von Neumann, J. and Morgenstern, O., (1947), Theory of Games and Economic Behavior, Princeton 1944, 2nd ed.

Wisner, J.D., Fawcett, S.E., (1991), Link firm strategy to operating decisions through performance measurement. Prod. Inventory Management. J. 32 (3), 5–11.

Yeniyurt S., (2003), A literature review and integrative performance measurement framework for multinational companies, Marketing Intelligence and Planning 21 (3) 134–142.

APPENDIX A
TERM DEFINITION

Batch: A quantity of items that are processed together (Michels, 2007) (Marchwinski & Shook, 2003).

Changeover: The process of switching from the production of one product or part number to another in a machine or a series of linked machines by changing parts, dies, molds or fixtures, also called a set-up. Changeover time is measured as the time elapsed between the last pieces in the run just completed until the first good piece from the process after the changeover (Marchwinski & Shook, 2003).

External Setup: That part of the setup which can be done while the machine is still running, for example, preparing a die to be used for the next run (Rubrich & Watson, 2004).

Internal Setup: That part of the setup which must be done while the machine is shut down, for example, removing or attaching dies (Rubrich & Watson, 2004).

Lot: A quantity of items that are processed together (Krajewski & Ritzman, 2007).

Setup: The process of switching from the production of one product or part number to another in a machine or a series of linked machines by changing parts, dies, molds or fixtures, also called a set-up. Changeover time is measured as the time elapsed between the last pieces in the run just completed until the first good piece from the process after the changeover (Marchwinski & Shook, 2003).

Setup Reduction: The process of reducing the amount of time needed to changeover a process from the last part for the previous product to the first good part for the next product (Marchwinski & Shook, 2003).

Setup Waste, External: Activities such as searching, locating or moving jigs, tools, bolts, clamps, fasteners, gauges or instructions in the setup area (Rubrich & Watson, 2004).

Setup Waste, Internal: Alignment activities required to remove and install tools, for example, the time associated with using a fork truck to maneuver the old tool out and the new tool in while setting up a press (Rubrich & Watson, 2004).

Waste: Any activity that consumes resources but creates no value for the customer (Marchwinski & Shook, 2003).

APPENDIX B
THE INTERNAL ACTIVITY FOR FAIR DISTRIBUTION

Contributor	P1	P2	P3	P4	Sum(I)
Jan'11	9	10	8	8	35
Feb'11	9	10	8	8	35
March'11	9	10	8	8	35
April'11	8.5	9.5	7.5	9	34.5
May'11	7	9.5	7.5	8	32
June'11	7	9.5	7.5	8	32
July'11	6	9.5	7.5	8	31
Aug'11	6	9	7	8	30
Sept'11	6	9	7	8	30
Oct'11	6	9	7	8	30
Nov'11	6	9	7	8	30
Dec'11	6	9	7	8	30
Jan'12	6	9	7	8	30
Feb'12	6	9	7	8	30
March'12	6	9	7	8	30
April'12	6	8.5	7	7	28.5
May'12	5.5	8.5	7	7	28
June'12	5.5	8.5	6	7	27
July'12	5.5	8.5	6	7	27
Aug'12	5.5	8.5	6	7	27
Sept'12	5	8	6	7	26
Oct'12	5	8	6	7	26
Nov'12	5	8	6	7	26
Dec'12	5	8	6	7	26
Jan'13	5	7.5	6	7	25.5
Feb'13	5	7	6	7	25
March'13	5	6	5	7	23
April'13	5	6	5	7	23
May'13	4	5.5	4.5	7	21
June'13	4	5	4	7	20
July'13	4	5	4	6	19
Aug'13	4	4.5	3.5	6	18
Sept'13	4	4.5	3.5	4.5	16.5
Oct'13	4	5	3.5	4.5	17
Nov'13	4	4.5	3.5	4.5	16.5
Dec'13	4	4.5	3.5	3.5	15.5
Jan'14	4	4	3	3	14
Feb'14	4	4	3	3	14
March'14	4	4	2.5	2.5	13
April'14	4	4	2.5	2.5	13
May'14	4	4	2.5	2.5	13

June'14	4	3.5	2.5	2.5	12.5
July'14	3.5	3.5	2.5	2.5	12
Aug'14	3.5	3.5	2.5	2.5	12
Sept'14	3.5	3.5	2.5	2.5	12
Oct'14	3.5	3.5	2.5	2.5	12
Nov'14	3.5	3.5	2.5	2.5	12
Dec'14	3.5	3.5	2.5	2.5	12

APPENDIX C
THE EXTERNAL ACTIVITY FOR FAIR DISTRIBUTION

Contributor	P5	P6	P7	Sum(O)
Jan'11	5	6	4	15
Feb'11	5	6	4	15
March'11	5	6	4	15
April'11	5	6	4	15
May'11	5	6	4	15
June'11	5	6	4	15
July'11	4.5	6	4	14.5
Aug'11	4.5	6	4	14.5
Sept'11	4.5	6	4	14.5
Oct'11	4.5	6	4	14.5
Nov'11	4.5	5.5	4	14
Dec'11	4.5	5.5	4	14
Jan'12	4.5	5.5	4	14
Feb'12	4.5	5.5	4	14
March'12	4.5	5.5	4	14
April'12	4	5	4	13
May'12	4.5	5	3.5	13
June'12	4.5	5	4	13.5
July'12	4.5	5	4	13.5
Aug'12	4.5	5	4	13.5
Sept'12	4	5	4	13
Oct'12	4	5	4	13
Nov'12	4	5	4	13
Dec'12	4	4.5	4	12.5
Jan'13	4	4.5	3.5	12
Feb'13	4	4	3	11
March'13	4	4	3	11
April'13	4	4	3	11
May'13	3.5	4	3	10.5
June'13	3.5	4	3	10.5
July'13	3.5	4	3	10.5
Aug'13	3.5	4	3	10.5
Sept'13	3.5	4	3	10.5
Oct'13	3.5	4	3	10.5
Nov'13	3.5	3.5	3	10
Dec'13	3.5	3.5	3	10
Jan'14	3.5	3.5	3	10
Feb'14	3.5	3.5	3	10
March'14	3.5	3.5	3	10
April'14	3	3.5	3	9.5
May'14	3	3.5	2.5	9

June'14	3	3.5	2.5	9
July'14	3	3.5	2.5	9
Aug'14	3	3.5	2.5	9
Sept'14	3	3.5	2.5	9
Oct'14	3	3	2	8
Nov'14	3	3	2	8
Dec'14	3	3	2	8

APPENDIX D
NORMALIZED VALUE FOR INTERNAL ACTIVITY

Contributor	P1	P2	P3	P4	Sum (I)
Jan'11	0.257143	0.285714	0.228571	0.228571	1
Feb'11	0.257143	0.285714	0.228571	0.228571	1
March'11	0.257143	0.285714	0.228571	0.228571	1
April'11	0.246377	0.275362	0.217391	0.26087	1
May'11	0.21875	0.296875	0.234375	0.25	1
June'11	0.21875	0.296875	0.234375	0.25	1
July'11	0.193548	0.306452	0.241935	0.258065	1
Aug'11	0.2	0.3	0.233333	0.266667	1
Sept'11	0.2	0.3	0.233333	0.266667	1
Oct'11	0.2	0.3	0.233333	0.266667	1
Nov'11	0.2	0.3	0.233333	0.266667	1
Dec'11	0.2	0.3	0.233333	0.266667	1
Jan'12	0.2	0.3	0.233333	0.266667	1
Feb'12	0.2	0.3	0.233333	0.266667	1
March'12	0.2	0.3	0.233333	0.266667	1
April'12	0.210526	0.298246	0.245614	0.245614	1
May'12	0.196429	0.303571	0.25	0.25	1
June'12	0.203704	0.314815	0.222222	0.259259	1
July'12	0.203704	0.314815	0.222222	0.259259	1
Aug'12	0.203704	0.314815	0.222222	0.259259	1
Sept'12	0.192308	0.307692	0.230769	0.269231	1
Oct'12	0.192308	0.307692	0.230769	0.269231	1
Nov'12	0.192308	0.307692	0.230769	0.269231	1
Dec'12	0.192308	0.307692	0.230769	0.269231	1
Jan'13	0.196078	0.294118	0.235294	0.27451	1
Feb'13	0.2	0.28	0.24	0.28	1
March'13	0.217391	0.26087	0.217391	0.304348	1
April'13	0.217391	0.26087	0.217391	0.304348	1
May'13	0.190476	0.261905	0.214286	0.333333	1
June'13	0.2	0.25	0.2	0.35	1
July'13	0.210526	0.263158	0.210526	0.315789	1
Aug'13	0.222222	0.25	0.194444	0.333333	1
Sept'13	0.242424	0.272727	0.212121	0.272727	1
Oct'13	0.235294	0.294118	0.205882	0.264706	1
Nov'13	0.242424	0.272727	0.212121	0.272727	1
Dec'13	0.258065	0.290323	0.225806	0.225806	1
Jan'14	0.285714	0.285714	0.214286	0.214286	1
Feb'14	0.285714	0.285714	0.214286	0.214286	1
March'14	0.307692	0.307692	0.192308	0.192308	1
April'14	0.307692	0.307692	0.192308	0.192308	1
May'14	0.307692	0.307692	0.192308	0.192308	1

June'14	0.32	0.28	0.2	0.2	1
July'14	0.291667	0.291667	0.208333	0.208333	1
Aug'14	0.291667	0.291667	0.208333	0.208333	1
Sept'14	0.291667	0.291667	0.208333	0.208333	1
Oct'14	0.291667	0.291667	0.208333	0.208333	1
Nov'14	0.291667	0.291667	0.208333	0.208333	1
Dec'14	0.291667	0.291667	0.208333	0.208333	1

APPENDIX E
NORMALIZED VALUE FOR EXTERNAL ACTIVITY

Contributor	P5	P6	P7	Sum (O)
Jan'11	0.333333	0.4	0.266667	1
Feb'11	0.333333	0.4	0.266667	1
March'11	0.333333	0.4	0.266667	1
April'11	0.333333	0.4	0.266667	1
May'11	0.333333	0.4	0.266667	1
June'11	0.333333	0.4	0.266667	1
July'11	0.310345	0.413793	0.275862	1
Aug'11	0.310345	0.413793	0.275862	1
Sept'11	0.310345	0.413793	0.275862	1
Oct'11	0.310345	0.413793	0.275862	1
Nov'11	0.321429	0.392857	0.285714	1
Dec'11	0.321429	0.392857	0.285714	1
Jan'12	0.321429	0.392857	0.285714	1
Feb'12	0.321429	0.392857	0.285714	1
March'12	0.321429	0.392857	0.285714	1
April'12	0.307692	0.384615	0.307692	1
May'12	0.346154	0.384615	0.269231	1
June'12	0.333333	0.37037	0.296296	1
July'12	0.333333	0.37037	0.296296	1
Aug'12	0.333333	0.37037	0.296296	1
Sept'12	0.307692	0.384615	0.307692	1
Oct'12	0.307692	0.384615	0.307692	1
Nov'12	0.307692	0.384615	0.307692	1
Dec'12	0.32	0.36	0.32	1
Jan'13	0.333333	0.375	0.291667	1
Feb'13	0.363636	0.363636	0.272727	1
March'13	0.363636	0.363636	0.272727	1
April'13	0.363636	0.363636	0.272727	1
May'13	0.333333	0.380952	0.285714	1
June'13	0.333333	0.380952	0.285714	1
July'13	0.333333	0.380952	0.285714	1
Aug'13	0.333333	0.380952	0.285714	1
Sept'13	0.333333	0.380952	0.285714	1
Oct'13	0.333333	0.380952	0.285714	1
Nov'13	0.35	0.35	0.3	1
Dec'13	0.35	0.35	0.3	1
Jan'14	0.35	0.35	0.3	1
Feb'14	0.35	0.35	0.3	1
March'14	0.35	0.35	0.3	1
April'14	0.315789	0.368421	0.315789	1
May'14	0.333333	0.388889	0.277778	1

June'14	0.333333	0.388889	0.277778	1
July'14	0.333333	0.388889	0.277778	1
Aug'14	0.333333	0.388889	0.277778	1
Sept'14	0.333333	0.388889	0.277778	1
Oct'14	0.375	0.375	0.25	1
Nov'14	0.375	0.375	0.25	1
Dec'14	0.375	0.375	0.25	1

APPENDIX F
COALITION VALUE FOR INTERNAL ACTIVITY BETWEEN TWO PLAYERS

Contributor	P1,P2	P1,P3	P1,P4	P2,P3	P2,P4	P3,P4
Jan'11	0.54286	0.48571	0.48571	0.51429	0.51429	0.45714
Feb'11	0.54286	0.48571	0.48571	0.51429	0.51429	0.45714
March'11	0.54286	0.48571	0.48571	0.51429	0.51429	0.45714
April'11	0.52174	0.46377	0.50725	0.49275	0.53623	0.47826
May'11	0.51563	0.45313	0.46875	0.53125	0.54688	0.48438
June'11	0.51563	0.45313	0.46875	0.53125	0.54688	0.48438
July'11	0.50000	0.43548	0.45161	0.54839	0.56452	0.50000
Aug'11	0.50000	0.43333	0.46667	0.53333	0.56667	0.50000
Sept'11	0.50000	0.43333	0.46667	0.53333	0.56667	0.50000
Oct'11	0.50000	0.43333	0.46667	0.53333	0.56667	0.50000
Nov'11	0.50000	0.43333	0.46667	0.53333	0.56667	0.50000
Dec'11	0.50000	0.43333	0.46667	0.53333	0.56667	0.50000
Jan'12	0.50000	0.43333	0.46667	0.53333	0.56667	0.50000
Feb'12	0.50000	0.43333	0.46667	0.53333	0.56667	0.50000
March'12	0.50000	0.43333	0.46667	0.53333	0.56667	0.50000
April'12	0.50877	0.45614	0.45614	0.54386	0.54386	0.49123
May’12	0.50000	0.44643	0.44643	0.55375	0.55375	0.50000
June'12	0.51852	0.42593	0.46296	0.53704	0.57407	0.48148
July'12	0.51852	0.42593	0.46296	0.53704	0.57407	0.48148
Aug'12	0.51852	0.42593	0.46296	0.53704	0.57407	0.48148
Sept'12	0.50000	0.42308	0.46154	0.53846	0.57692	0.50000
Oct'12	0.50000	0.42308	0.46154	0.53846	0.57692	0.50000
Nov'12	0.50000	0.42308	0.46154	0.53846	0.57692	0.50000
Dec'12	0.50000	0.42308	0.46154	0.53846	0.57692	0.50000
Jan'13	0.49020	0.43137	0.47059	0.52941	0.56863	0.50980
Feb'13	0.48000	0.44000	0.48000	0.52000	0.56000	0.52000
March'13	0.47826	0.43478	0.52174	0.47826	0.56522	0.52174
April'13	0.47826	0.43478	0.52174	0.47826	0.56522	0.52174
May'13	0.45238	0.40476	0.52381	0.47619	0.59524	0.54762
June’13	0.45000	0.40000	0.55000	0.45000	0.60000	0.55000
July'13	0.47368	0.42105	0.52632	0.47368	0.57895	0.52632
Aug'13	0.47222	0.41667	0.55556	0.44444	0.58333	0.52778
Sept'13	0.51515	0.45455	0.51515	0.48485	0.54545	0.48485
Oct'13	0.52941	0.44118	0.50000	0.50000	0.55882	0.47059
Nov'13	0.51515	0.45455	0.51515	0.48485	0.54545	0.48485
Dec'13	0.54839	0.48387	0.48387	0.51613	0.51613	0.45161
Jan'14	0.57143	0.50000	0.50000	0.50000	0.50000	0.42857
Feb'14	0.57143	0.50000	0.50000	0.50000	0.50000	0.42857
March’14	0.61538	0.50000	0.50000	0.50000	0.50000	0.38462
April'14	0.61538	0.50000	0.50000	0.50000	0.50000	0.38462

May'14	0.61538	0.50000	0.50000	0.50000	0.50000	0.38462
June'14	0.60000	0.52000	0.52000	0.48000	0.48000	0.40000
July'14	0.58333	0.50000	0.50000	0.50000	0.50000	0.41667
Aug'14	0.58333	0.50000	0.50000	0.50000	0.50000	0.41667
Sept'14	0.58333	0.50000	0.50000	0.50000	0.50000	0.41667
Oct'14	0.58333	0.50000	0.50000	0.50000	0.50000	0.41667
Nov'14	0.58333	0.50000	0.50000	0.50000	0.50000	0.41667
Dec'14	0.58333	0.50000	0.50000	0.50000	0.50000	0.41667

APPENDIX G
COALITION VALUE FOR INTERNAL ACTIVITY BETWEEN THREE PLAYERS

Contributor	P1,P2,P3	P1,P2,P4	P2,P3,P4	P1,P3,P4
Jan'11	0.77143	0.77143	0.74286	0.71429
Feb'11	0.77143	0.77143	0.74286	0.71429
March'11	0.77143	0.77143	0.74286	0.71429
April'11	0.73913	0.78261	0.75362	0.72464
May'11	0.75000	0.76563	0.78125	0.70313
June'11	0.75000	0.76563	0.78125	0.70313
July'11	0.74194	0.75806	0.80645	0.69355
Aug'11	0.73333	0.76667	0.80000	0.70000
Sept'11	0.73333	0.76667	0.80000	0.70000
Oct'11	0.73333	0.76667	0.80000	0.70000
Nov'11	0.73333	0.76667	0.80000	0.70000
Dec'11	0.73333	0.76667	0.80000	0.70000
Jan'12	0.73333	0.76667	0.80000	0.70000
Feb'12	0.73333	0.76667	0.80000	0.70000
March'12	0.73333	0.76667	0.80000	0.70000
April'12	0.75439	0.75439	0.78947	0.70175
May'12	0.75000	0.75000	0.80357	0.69643
June'12	0.74074	0.77778	0.79630	0.68519
July'12	0.74074	0.77778	0.79630	0.68519
Aug'12	0.74074	0.77778	0.79630	0.68519
Sept'12	0.73077	0.76923	0.80769	0.69231
Oct'12	0.73077	0.76923	0.80769	0.69231
Nov'12	0.73077	0.76923	0.80769	0.69231
Dec'12	0.73077	0.76923	0.80769	0.69231
Jan’13	0.72549	0.76471	0.80392	0.70588
Feb’13	0.72000	0.76000	0.80000	0.72000
March’13	0.69565	0.78261	0.78261	0.73913
April’13	0.69565	0.78261	0.78261	0.73913
May’13	0.66667	0.78571	0.80952	0.73810
June’13	0.65000	0.80000	0.80000	0.75000
July’13	0.68421	0.78947	0.78947	0.73684
Aug’13	0.66667	0.80556	0.77778	0.75000
Sept’13	0.72727	0.78788	0.75758	0.72727
Oct’13	0.73529	0.79412	0.76471	0.70588
Nov’13	0.72727	0.78788	0.75758	0.72727
Dec’13	0.77419	0.77419	0.74194	0.70968
Jan’14	0.78571	0.78571	0.71429	0.71429
Feb’14	0.78571	0.78571	0.71429	0.71429
March’14	0.80769	0.80769	0.69231	0.69231
April'14	0.80769	0.80769	0.69231	0.69231

May'14	0.80769	0.80769	0.69231	0.69231
June'14	0.80000	0.80000	0.68000	0.72000
July'14	0.79167	0.79167	0.70833	0.70833
Aug'14	0.79167	0.79167	0.70833	0.70833
Sept'14	0.79167	0.79167	0.70833	0.70833
Oct'14	0.79167	0.79167	0.70833	0.70833
Nov'14	0.79167	0.79167	0.70833	0.70833
Dec'14	0.79167	0.79167	0.70833	0.70833

APPENDIX H
COALITION VALUE FOR EXTERNAL ACTIVITY BETWEEN TWO PLAYERS

Contributor	P5,P6	P5,P7	P6,P7
Jan'11	0.73333	0.60000	0.66667
Feb'11	0.73333	0.60000	0.66667
March'11	0.73333	0.60000	0.66667
April'11	0.73333	0.60000	0.66667
May'11	0.73333	0.60000	0.66667
June'11	0.73333	0.60000	0.66667
July'11	0.72414	0.58621	0.68966
Aug'11	0.72414	0.58621	0.68966
Sept'11	0.72414	0.58621	0.68966
Oct'11	0.72414	0.58621	0.68966
Nov'11	0.71429	0.60714	0.67857
Dec'11	0.71429	0.60714	0.67857
Jan'12	0.71429	0.60714	0.67857
Feb'12	0.71429	0.60714	0.67857
March'12	0.71429	0.60714	0.67857
April'12	0.69231	0.61538	0.69231
May'12	0.73077	0.61538	0.65385
June'12	0.70370	0.62963	0.66667
July'12	0.70370	0.62963	0.66667
Aug'12	0.70370	0.62963	0.66667
Sept'12	0.69231	0.61538	0.69231
Oct'12	0.69231	0.61538	0.69231
Nov'12	0.69231	0.61538	0.69231
Dec'12	0.68000	0.64000	0.68000
Jan'13	0.70833	0.62500	0.66667
Feb'13	0.72727	0.63636	0.63636
March'13	0.72727	0.63636	0.63636
April'13	0.72727	0.63636	0.63636
May'13	0.71429	0.61905	0.66667
June'13	0.71429	0.61905	0.66667
July'13	0.71429	0.61905	0.66667
Aug'13	0.71429	0.61905	0.66667
Sept'13	0.71429	0.61905	0.66667
Oct'13	0.71429	0.61905	0.66667
Nov'13	0.70000	0.65000	0.65000
Dec'13	0.70000	0.65000	0.65000
Jan'14	0.70000	0.65000	0.65000
Feb'14	0.70000	0.65000	0.65000
March'14	0.70000	0.65000	0.65000
April'14	0.68421	0.63158	0.68421

May'14	0.72222	0.61111	0.66667
June'14	0.72222	0.61111	0.66667
July'14	0.72222	0.61111	0.66667
Aug'14	0.72222	0.61111	0.66667
Sept'14	0.72222	0.61111	0.66667
Oct'14	0.75000	0.62500	0.62500
Nov'14	0.75000	0.62500	0.62500
Dec'14	0.75000	0.62500	0.62500

APPENDIX I

PERMUTATION CREATED BY COALITION BETWEEN CONTRIBUTOR AND PLAYER FOR INTERNAL ACTIVITY

Contributor	P1	P2	P3	P4
P1,P2,P3,P4	0.32000	0.29538	0.19231	0.19231
P1,P2,P4,P3	0.32000	0.29538	0.19231	0.19231
P1,P3,P2,P4	0.32000	0.28769	0.20000	0.19231
P1,P3,P4,P2	0.32000	0.25000	0.20000	0.23000
P1,P4,P3,P2	0.32000	0.25000	0.20000	0.23000
P1,P4,P2,P3	0.32000	0.25769	0.19231	0.23000
P2,P1,P3,P4	0.30057	0.31481	0.19231	0.19231
P2,P1,P4,P3	0.29538	0.31481	0.19231	0.19231
P2,P3,P1,P4	0.25412	0.31481	0.23876	0.19231
P2,P3,P4,P1	0.19231	0.31481	0.23876	0.25412
P2,P4,P1,P3	0.20769	0.31481	0.19231	0.28519
P2,P4,P3,P1	0.19231	0.31481	0.20769	0.28519
P3,P1,P2,P4	0.27000	0.28769	0.25000	0.19231
P3,P1,P4,P2	0.27000	0.25000	0.25000	0.23000
P3,P2,P1,P4	0.25412	0.30357	0.25000	0.19231
P3,P2,P4,P1	0.19231	0.30357	0.25000	0.25412
P3,P4,P1,P2	0.20000	0.25000	0.25000	0.30000
P3,P4,P2,P1	0.19231	0.25769	0.25000	0.30000
P4,P1,P2,P3	0.20000	0.25769	0.19231	0.35000
P4,P1,P3,P2	0.20000	0.25000	0.20000	0.35000
P4,P2,P1,P3	0.20769	0.25000	0.19231	0.35000
P4,P2,P3,P1	0.19231	0.25000	0.20769	0.35000
P4,P3,P1,P2	0.20000	0.25000	0.20000	0.35000
P4,P3,P2,P1	0.19231	0.25769	0.20000	0.35000
Sum	5.93343	6.69295	5.13136	6.23707
Mean	0.247226	0.2788731	0.2138066	0.2598781

APPENDIX J
PERMUTATION CREATED BY COALITION BETWEEN CONTRIBUTOR AND PLAYER FOR EXTERNAL ACTIVITY

Contributor	P5	P6	P7
P5,P6,P7	0.37500	0.37500	0.25000
P5,P7,P6	0.37500	0.35000	0.27500
P6,P7,P5	0.30769	0.41379	0.27851
P6,P5,P7	0.33621	0.41379	0.25000
P7,P5,P6	0.33000	0.35000	0.32000
P7,P6,P5	0.30769	0.37231	0.32000
Sum	2.03159	2.27489	1.69351
Mean	0.338599	0.379149	0.282252
SoB	0.893049	1	0.744437
SoB (%)	89	100	74

APPENDIX K
1ST SUB-COALITION MARGINAL CONTRIBUTION

Contributor	t_1	t_2	t_3	t_4	t_5
t1,t2,t3,t4,t5	0.211765	0.211765	0.211765	0.2	0.164706
t1,t2,t3,t5,t4	0.211765	0.211765	0.211765	0.192308	0.172398
t1,t2,t4,t5,t3	0.211765	0.211765	0.195122	0.211765	0.169584
t1,t2,t4,t3,t5	0.211765	0.211765	0.2	0.211765	0.164706
t1,t2,t5,t3,t4	0.211765	0.211765	0.205128	0.192308	0.179035
t1,t2,t5,t4,t3	0.211765	0.211765	0.195122	0.202314	0.179035
t1,t3,t4,t5,t2	0.211765	0.195122	0.211765	0.2	0.181349
t1,t3,t4,t2,t5	0.211765	0.184163	0.211765	0.2	0.164706
t1,t3,t2,t4,t5	0.211765	0.211765	0.211765	0.2	0.164706
t1,t3,t2,t5,t4	0.211765	0.211765	0.211765	0.192308	0.172398
t1,t3,t5,t2,t4	0.211765	0.205128	0.211765	0.192308	0.179035
t1,t3,t5,t4,t2	0.211765	0.195122	0.211765	0.202314	0.179035
t1,t4,t5,t2,t3	0.211765	0.195122	0.195122	0.202869	0.195122
t1,t4,t5,t3,t2	0.211765	0.195122	0.195122	0.202869	0.195122
t1,t4,t3,t5,t2	0.211765	0.195122	0.208895	0.202869	0.181349
t1,t4,t3,t2,t5	0.211765	0.211765	0.208895	0.202869	0.164706
t1,t4,t2,t3,t5	0.211765	0.22066	0.2	0.202869	0.164706
t1,t4,t2,t5,t3	0.211765	0.22066	0.195122	0.202869	0.169584
t1,t5,t4,t3,t2	0.211765	0.195122	0.195122	0.211797	0.186194
t1,t5,t4,t2,t3	0.211765	0.195122	0.195122	0.211797	0.186194
t1,t5,t3,t2,t4	0.211765	0.205128	0.204605	0.192308	0.186194
t1,t5,t3,t4,t2	0.211765	0.195122	0.204605	0.202314	0.186194
t1,t5,t2,t3,t4	0.211765	0.204605	0.205128	0.192308	0.186194
t1,t5,t2,t4,t3	0.211765	0.204605	0.195122	0.202314	0.186194
t2,t1,t3,t4,t5	0.211765	0.211765	0.211765	0.2	0.164706
t2,t1,t3,t5,t4	0.211765	0.211765	0.211765	0.192308	0.172398
t2,t1,t4,t5,t3	0.211765	0.211765	0.195122	0.211765	0.169584
t2,t1,t4,t3,t5	0.211765	0.211765	0.2	0.211765	0.164706
t2,t1,t5,t3,t4	0.211765	0.211765	0.205128	0.192308	0.179035
t2,t1,t5,t4,t3	0.211765	0.211765	0.195122	0.202314	0.179035
t2,t3,t4,t5,t1	0.195122	0.211765	0.211765	0.2	0.181349
t2,t3,t4,t1,t5	0.211765	0.211765	0.211765	0.2	0.164706
t2,t3,t5,t1,t4	0.205128	0.211765	0.211765	0.192308	0.179035
t2,t3,t5,t4,t1	0.195122	0.211765	0.211765	0.202314	0.179035
t2,t3,t1,t5,t4	0.211765	0.211765	0.211765	0.192308	0.172398
t2,t3,t1,t4,t5	0.211765	0.211765	0.211765	0.2	0.164706
t2,t4,t1,t3,t5	0.22066	0.211765	0.2	0.202869	0.164706
t2,t4,t1,t5,t3	0.195122	0.211765	0.195122	0.202869	0.169584
t2,t4,t5,t1,t3	0.195122	0.211765	0.195122	0.202869	0.195122
t2,t4,t5,t3,t1	0.195122	0.211765	0.195122	0.202869	0.195122
t2,t4,t3.t1,t5	0.211765	0.211765	0.208895	0.202869	0.164706

t2,t4,t3,t5,t1	0.195122	0.211765	0.208895	0.202869	0.181349
t2,t5,t1,t3,t4	0.204605	0.211765	0.205128	0.192308	0.186194
t2,t5,t1,t4,t3	0.204605	0.211765	0.195122	0.202314	0.186194
t2,t5,t3,t4t1	0.195122	0.211765	0.204605	0.202314	0.186194
t2,t5,t3,t1,t4	0.205128	0.211765	0.204605	0.192308	0.186194
t2,t5,t4,t1,t3	0.195122	0.211765	0.195122	0.211797	0.186194
t2,t5,t4,t3,t1	0.195122	0.211765	0.195122	0.211797	0.186194
t3,t2,t1,t4,t5	0.211765	0.211765	0.211765	0.2	0.164706
t3,t2,t1,t5,t4	0.211765	0.211765	0.211765	0.192308	0.172398
t3,t2,t4,t5,t1	0.195122	0.211765	0.211765	0.2	0.181349
t3,t2,t4,t1,t5	0.211765	0.211765	0.211765	0.2	0.164706
t3,t2,t5,t4,t1	0.195122	0.211765	0.211765	0.202314	0.179035
t3,t2,t5,t1,t4	0.205128	0.211765	0.211765	0.192308	0.179035
t3,t4,t2,t1,t5	0.211765	0.208895	0.211765	0.202869	0.164706
t3,t4,t2,t5,t1	0.195122	0.208895	0.211765	0.202869	0.181349
t3,t4,t1,t5,t2	0.208895	0.195122	0.211765	0.202869	0.181349
t3,t4,t1,t2,t5	0.208895	0.211765	0.211765	0.202869	0.164706
t3,t4,t5,t1,t2	0.195122	0.195122	0.211765	0.202869	0.195122
t3,t4,t5,t2,t1	0.195122	0.195122	0.211765	0.202869	0.195122
t3,t5,t1,t2,t4	0.204605	0.205128	0.211765	0.192308	0.186194
t3,t5,t1,t4,t2	0.204605	0.195122	0.211765	0.202314	0.186194
t3,t5,t2,t4,t1	0.195122	0.204605	0.211765	0.202314	0.186194
t3,t5,t2,t1,t4	0.205128	0.204605	0.211765	0.192308	0.186194
t3,t5,t4,t2,t1	0.195122	0.195122	0.211765	0.211797	0.186194
t3,t5,t4,t1,t2	0.195122	0.195122	0.211765	0.211797	0.186194
t3,t1,t2,t4,t5	0.211765	0.211765	0.211765	0.2	0.164706
t3,t1,t2,t5,t4	0.211765	0.211765	0.211765	0.192308	0.172398
t3,t1,t4,t5,t2	0.211765	0.195122	0.211765	0.2	0.181349
t3,t1,t4,t2,t5	0.211765	0.211765	0.211765	0.2	0.164706
t3,t1,t5,t2,t4	0.211765	0.205128	0.211765	0.192308	0.179035
t3,t1,t5,t4,t2	0.211765	0.195122	0.211765	0.202314	0.179035
t4,t5,t1,t2,t3	0.195122	0.195122	0.195122	0.219512	0.195122
t4,t5,t1,t3,t2	0.195122	0.195122	0.195122	0.219512	0.195122
t4,t5,t2,t3,t1	0.195122	0.195122	0.195122	0.219512	0.195122
t4,t5,t2,t1,t3	0.195122	0.195122	0.195122	0.219512	0.195122
t4,t5,t3,t1,t2	0.195122	0.195122	0.195122	0.219512	0.195122
t4,t5,t3,t2,t1	0.195122	0.195122	0.195122	0.219512	0.195122
t4,t3,t2,t1,t5	0.211765	0.208895	0.195122	0.219512	0.164706
t4,t3,t2,t5,t1	0.195122	0.208895	0.195122	0.219512	0.181349
t4,t3,t5,t1,t2	0.195122	0.195122	0.195122	0.219512	0.195122
t4,t3,t5,t2,t1	0.195122	0.195122	0.195122	0.219512	0.195122
t4,t3,t1,t5,t2	0.208895	0.195122	0.195122	0.219512	0.181349
t4,t3,t1,t2,t5	0.208895	0.211765	0.195122	0.219512	0.164706
t4,t2,t1,t3,t5	0.22066	0.195122	0.2	0.219512	0.164706
t4,t2,t1,t5,t3	0.22066	0.195122	0.195122	0.219512	0.169584
t4,t2,t3,t1,t5	0.211765	0.195122	0.208895	0.219512	0.164706

t4,t2,t3,t5,t1	0.195122	0.195122	0.208895	0.219512	0.181349
t4,t2,t5,t1,t3	0.195122	0.195122	0.195122	0.219512	0.195122
t4,t2,t5,t3,t1	0.195122	0.195122	0.195122	0.219512	0.195122
t4,t1,t2,t3,t5	0.195122	0.22066	0.2	0.219512	0.164706
t4,t1,t2,t5,t3	0.195122	0.22066	0.195122	0.219512	0.169584
t4,t1,t3,t5,t2	0.195122	0.195122	0.208895	0.219512	0.181349
t4,t1,t3,t2,t5	0.195122	0.211765	0.208895	0.219512	0.164706
t4,t1,t5,t2,t3	0.195122	0.195122	0.195122	0.219512	0.195122
t4,t1,t5,t3,t2	0.195122	0.195122	0.195122	0.219512	0.195122
t5,t4,t3,t2,t1	0.195122	0.195122	0.195122	0.219512	0.195122
t5,t4,t3,t1,t2	0.195122	0.195122	0.195122	0.219512	0.195122
t5,t4,t2,t1,t3	0.195122	0.195122	0.195122	0.219512	0.195122
t5,t4,t2,t3,t1	0.195122	0.195122	0.195122	0.219512	0.195122
t5,t4,t1,t2,t3	0.195122	0.195122	0.195122	0.219512	0.195122
t5,t4,t1,t3,t2	0.195122	0.195122	0.195122	0.219512	0.195122
t5,t3,t4,t2,t1	0.195122	0.195122	0.202837	0.211797	0.195122
t5,t3,t4,t1,t2	0.195122	0.195122	0.202837	0.195122	0.195122
t5,t3,t2,t1,t4	0.205128	0.204605	0.202837	0.192308	0.195122
t5,t3,t2,t4,t1	0.195122	0.204605	0.202837	0.202314	0.195122
t5,t3,t1,t2,t4	0.204605	0.205128	0.202837	0.192308	0.195122
t5,t3,t1,t4,t2	0.204605	0.195122	0.202837	0.202314	0.195122
t5,t2,t1,t3,t4	0.204605	0.202837	0.205128	0.192308	0.195122
t5,t2,t1,t4,t3	0.204605	0.202837	0.195122	0.202314	0.195122
t5,t2,t3,t4,t1	0.195122	0.202837	0.204605	0.202314	0.195122
t5,t2,t3,t1,t4	0.205128	0.202837	0.204605	0.192308	0.195122
t5,t2,t4,t1,t3	0.195122	0.202837	0.195122	0.211797	0.195122
t5,t2,t4,t3,t1	0.195122	0.202837	0.195122	0.211797	0.195122
t5,t1,t2,t3,t4	0.202837	0.204605	0.205128	0.192308	0.195122
t5,t1,t2,t4,t3	0.202837	0.204605	0.195122	0.202314	0.195122
t5,t1,t3,t4,t2	0.202837	0.195122	0.204605	0.202314	0.195122
t5,t1,t3,t2,t4	0.202837	0.205128	0.204605	0.192308	0.195122
t5,t1,t4,t3,t2	0.202837	0.195122	0.195122	0.211797	0.195122
t5,t1,t4,t2,t3	0.202837	0.195122	0.195122	0.211797	0.195122
sum	24.4941	24.49204	24.40199	24.666	21.87606
average	0.204118	0.2041	0.20335	0.20555	0.1823

APPENDIX L

PERMUTATION OF 44 SUB COALITION CREATED FROM $t_1 - t_{48}$ FOR INTERNAL ACTIVITY USING MCA

	t1	t2	t3	t4	t5	t6	t7	t8	t9	t10	t11	t12	t13	t14	t15	t16	t17	t18	t19	t20	t21	t22	t23	t24
1st	1	0.999916	0.99624	1.007018	0.893115																			
2nd		0.99923	1	0.999765	0.889469	0.888558																		
3rd			1	0.984045	0.880347	0.880347	0.829429																	
4th				1	0.892491	0.891939	0.841551	0.81981																
5th					1	1.000994	0.937011	0.91685	0.91685															
6th						1	0.937735	0.925085	0.925085	0.925085														
7th							1	0.966096	0.965753	0.965753	0.965753													
8th								1	1	1	1	1												
9th									1	1	1	1	1											
10th										1	1	1	1	1										
11th											1	1	1	1	1									
12th												1	0.937735	0.925085	0.925085	0.925085								
13th													1	0.995559	0.995559	0.947964	0.929613							
14th														0.999555	1	0.945995	0.936549	0.886269						
15th															1	0.951694	0.939516	0.88626	0.88626					
16th																1	0.98288	0.920226	0.920226	0.920226				
17th																	1	0.934932	0.934791	0.934791	0.908521			
18th																		0.999846	1	1	0.953704	0.953704		
19th																			0.999377	1	0.953271	0.953271	0.953271	
20th																				1	0.953302	0.95283	0.95283	0.95283
21st																					0.999686	0.999581	1	1
22nd																						0.999575	0.999469	1
23rd																							1	0.993554
24th																								1
25th																								

	t25	t26	t27	t28	t29	t30	t31	t32	t33	t34	t35	t36	t37	t38	t39	t40	t41	t42	t43	t44	t45	t46	t47	t48	sum	Avg. SoB
21st	0.968553																								4.96782	0.993564
22nd	0.968153	0.936306																							4.903503	0.980701
23rd	0.976188	0.952229	0.860726																						4.782698	0.95654
24th	0.976076	0.95531	0.868354	0.868354																					4.668095	0.933619
25th	1	0.985216	0.921755	0.921755	0.842705																				4.671432	0.934286
26th		1	0.940825	0.940145	0.854329	0.818966																			4.554265	0.910853
27th			0.998305	1	0.902851	0.880085	0.823968																		4.605209	0.921042
28th				1	0.90301	0.878407	0.829162	0.797719																	4.408299	0.88166
29th					1	0.985898	0.923704	0.888312	0.808067																4.60598	0.921196
30th						1	0.931023	0.904985	0.803019	0.820256															4.459283	0.891857
31st							1	0.965891	0.855267	0.876862	0.855267														4.553288	0.910658
32nd								1	0.873919	0.902275	0.870715	0.774111													4.421019	0.884204
33rd									0.9953	1	0.996286	0.898286	0.843677												4.73355	0.94671
34th										1	0.993489	0.895177	0.814383	0.814383											4.517432	0.903486
35th											1	0.897	0.80909	0.80909	0.745501										4.260681	0.852136
36th												1	0.913312	0.912761	0.844414	0.844414									4.5149	0.90298
37th													0.99883	1	0.912281	0.912281	0.912281								4.735673	0.947135
38th														1	0.92993	0.92993	0.92993	0.894895							4.684685	0.936937
39th															0.999375	0.999808	1	0.954575	0.917753						4.871512	0.974302
40th																0.999136	1	0.958269	0.918983	0.918983					4.79537	0.959074
41st																	1	0.960895	0.916485	0.916485	0.916485				4.71035	0.94207
42nd																		1	0.934868	0.934211	0.934211	0.934211			4.7375	0.9475
43rd																			1	1	1	1	1		5	1
44th																				1	1	1	1	1	5	1
sum	4.888971	4.829061	4.589966	4.730254	4.502895	4.563355	4.507858	4.556908	4.335571	4.599393	4.715757	4.464574	4.379293	4.536235	4.431501	4.685568	4.842211	4.768634	4.688089	4.769678	3.850695	2.934211	2	1		
average	0.977794	0.965812	0.917993	0.946051	0.900579	0.912671	0.901572	0.911382	0.867114	0.919879	0.943151	0.892915	0.875859	0.907247	0.8863	0.937114	0.968442	0.953727	0.937618	0.953936	0.962674	0.97807	1	1		

APPENDIX M
PERMUTATION OF 44 SUB COALITION CREATED FROM $t_1 - t_{48}$ FOR EXTERNAL ACTIVITY USING MCA

	t1	t2	t3	t4	t5	t6	t7	t8	t9	t10	t11	t12	t13	t14	t15	t16	t17	t18	t19	t20	t21	t22	t23	t24	t25	t26
1st	1	1	1	1	1																					
2nd		1	1	1	1	1																				
3rd			1	1	0.9993	1	0.9505																			
4th				1	1	1	0.9491	0.9495																		
5th					1	0.999	0.9402	0.9409	0.9405																	
6th						1	0.9483	0.9479	0.9479	0.9481																
7th							1	1	0.9994	1	0.9588															
8th								1	1	1	0.9578	0.9581														
9th									1	0.9999	0.9573	0.9571	0.9575													
10th										1	0.9572	0.9569	0.9569	0.957												
11th											1	1	1	1	1											
12th												1	1	0.9993	1	0.9449										
13th													1	1	0.9999	0.9487	0.9431									
14th														1	1	0.9341	0.9265	0.9691								
15th															1	0.9338	0.9264	0.9671	0.9684							
16th																0.9572	0.9502	0.9992	1	0.9985						
17th																	0.9556	0.9994	0.9993	1	0.9626					
18th																		1	1	1	0.9434	0.9438				
19th																			1	0.9989	0.9333	0.9341	0.9337			
20th																				1	0.9573	0.9532	0.9536	0.9256		
21st																					1	1	0.9997	0.9684	0.9271	
22nd																						1	1	0.9725	0.9317	0.864
23rd																							1	0.9817	0.9321	0.8577
24th																								1	0.9392	0.8644
25th																									1	0.9271

																							4.8917	0.9783	0.9721	97.834
																							4.8297	0.9659	0.9625	96.593
																							4.7957	0.9591	0.9701	95.914
																							4.905	0.981	0.9822	98.101
																							4.9168	0.9834	0.9804	98.337
																							4.8871	0.9774	0.9687	97.742
																							4.8	0.96	0.959	96
																							4.7897	0.9579	0.9685	95.793
																							4.8952	0.979	0.9663	97.904
0.864																							4.7682	0.9536	0.9399	95.364
0.8577	0.8588																						4.6304	0.9261	0.9163	92.608
0.8644	0.8639	0.8651																					4.5328	0.9066	0.9184	90.655
0.9271	0.9257	0.9262	0.8727																				4.6517	0.9303	0.9524	93.034
1	1	1	0.9361	0.9365																			4.8726	0.9745	0.9678	97.453
	1	0.9998	0.9351	0.9348	0.9355																		4.8052	0.961	0.9543	96.104
		1	0.9346	0.9342	0.9342	0.9344																	4.7375	0.9475	0.9738	94.75
			1	1	1	1	1																5	1	1	100
				1	1	1	1	1															5	1	0.9937	100
					1	1	0.9992	1	0.938														4.9371	0.9874	0.981	98.743
						1	1	1	0.9361	0.9365													4.8726	0.9745	0.9678	97.453
							1	0.9998	0.9351	0.9348	0.9355												4.8052	0.961	0.9561	96.104
								1	0.941	0.9406	0.9406	0.9342											4.7563	0.9513	0.9756	95.125
									1	1	1	1	1										5	1	0.9928	100
										1	1	0.999	1	0.929									4.928	0.9856	0.9779	98.56
											1	1	0.9996	0.9522	0.8994								4.8512	0.9702	0.9666	97.024
												1	1	0.9653	0.9242	0.9253							4.8147	0.9629	0.9462	96.295
													1	0.9597	0.8956	0.8955	0.8961						4.6469	0.9294	0.9291	92.938
														1	0.9113	0.9107	0.9107	0.911					4.6438	0.9288	0.9644	92.875
															1	1	1	1	1				5	1	0.9899	100
																1	1	0.9986	1	0.9			4.8986	0.9797	0.9692	97.973
																	1	1	1	0.8962	0.8969		4.7931	0.9586	0.9474	95.861
																		1	0.9996	0.8936	0.8933	0.8943	4.6809	0.9362	0.4681	93.617
4.5133	4.6485	4.7911	4.6785	4.8056	4.8697	4.9344	4.9992	4.9998	4.7501	4.8119	4.8761	4.9332	4.9996	4.8061	4.6305	4.7315	4.8068	4.9097	3.9996	2.6898	1.7901	0.8943				
0.9027	0.9297	0.9582	0.9357	0.9611	0.9739	0.9869	0.9998	1	0.95	0.9624	0.9752	0.9866	0.9999	0.9612	0.9261	0.9463	0.9614	0.9819	0.9999	0.8966	0.8951	0.8943				
0.9162	0.944	0.947	0.9484	0.9675	0.9804	0.9934	0.9999	0.975	0.9562	0.9688	0.9809	0.9933	0.9806	0.9437	0.9362	0.9538	0.9716	0.9909	0.9483	0.8958	0.8947	0.4472				