MODEL FOR DECISION MAKING IN IMPLEMENTING PROCESS IMRPOVEMENT

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MODEL FOR DECISION MAKING IN IMPLEMENTING PROCESS IMRPOVEMENT

by

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DECLARATION

I hereby declare that the work reported in this thesis is the result of my own investigation and that no part of the thesis has been plagiarized from external sources. Materials taken from other sources are duly acknowledged by giving explicit references.

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LIST OF ABBREVIATIONS

ANOVA	Analysis of variance
CL	Confidence level
CR	Consistency ratio
CS1	Case study 1
CS2	Case study 2
CS3	Case study 3
CS4	Case study 4
CS5	Case study 5
CS6	Case study 6
DES	Discrete event simulation
DOE	Design of experiment
DOF	Degrees of freedom
DOTWIMP	Defects, overproduction, transportation, waiting, inventory, motion, and over processing
FMEA	Failure mode and effect analysis
GRA	Grey relational analysis
GRA–EM	Grey relational analysis with entropy measurement
HB	Higher value is better
HOI	House of improvement
IC	Integrated-circuit
IPS	Improvement process selection

LB	Lower value is better
MCDM	Multi-criteria decision making
NB	Nominal value is best
NS	Normalized score
NVA	Non-value-added
NVAN	Non value-added but necessary
OA	Orthogonal array
OP	Operational parameter
P	Percentage contribution
PCB	Printed circuit board
QFD	Quality function deployment
SOP	Standard operation procedure
VA	Value-added
WIP	Work in progress
WS	Overall weighted score

LIST OF SYMBOLS

k_{α}	Number of criteria in the matrix for relationship rating
S_x^2	Variance of the relationship score
S_p^2	Variance of the total relationship score
n	Number of criteria
λ_{max}	Maximum eigenvalue of the matrix
W_x	Relative weight
S_{xy}	Rating score of the relationship
WS_{xy}	Overall weighted score
E(Y)	Average simulated result
Z	Specific value in the null hypothesis,
S	Standard deviation
n_r	Number of replications
t_n	Operating standard time of the nth process step
s_n	Number of assigned operators in the nth process step
t_0	Cycle time of the bottleneck station
a	Total number of assigned operators
x_{ij}	Normalized value in generation of grey relational
η_{ij}	Value of performance measure result
n_{ob}	Desired value of performance measure characteristics.
ε_{ij}	Grey relation coefficient
k	Normalized coefficient in weighting of grey relational coefficient

e_j	Entropy of each performance measure response
E	Sum of entropy
w_i	Weight of performance measure *i* from the entropy measurement
γ_j	Grey relational grade value
S_T	Total sums of squares
S_A	Factor sums of squares for operational parameter A
V_A	Mean squares for operational parameter A
F_A	F-ratio for operational parameter A
S'_A	Pure sum of squares for operational parameter A
P_A	Percentage contribution for operational parameter A

MODEL UNTUK MEMBUAT KEPUTUSAN DALAM MELAKSANAKAN PENAMBAHBAIKAN PROSES

ABSTRAK

Industri, terutama industri pembuatan, perlu bertindak balas dengan cepat dan berkesan dengan keperluan pelanggan dan menjadi pasaran yang kompetitif. Sebagai tindak balas kepada perubahan pesat maju di pasaran, industri diperlukan untuk terus memperbaiki proses operasi mereka untuk mengurangkan pembaziran di bahagian pengeluaran. Proses memilih penyelesaian untuk menyelesaikan masalah dari satu set alternatif adalah penting dalam menentukan kejayaan atau kegagalan proses penambahbaikan. Oleh itu, model penambahbaikan berkesan perlu dipertimbangkan dalam memperkenalkan penambahbaikan dalam pengeluaran melalui proses pemilihan penyelesaian struktur. Walau bagaimanapun, keutamaan dan pemilihan dalam bidang tumpuan dan langkah-langkah pembaikan telah diabaikan dalam peningkatan model sebelumnya. Berdasarkan kajian literatur, lima reka bentuk keperluan pembangunan model yang menyokong pemilihan penyelesaian telah dijumpai. Dengan memenuhi keperluan, model peningkatan baru, dipanggil sebagai pemilihan proses penambahbaikan (IPS) model telah dibangunkan dalam tiga peringkat: pengenalan, ramalan, dan pemilihan yang digunakan untuk memudahkan proses membuat keputusan yang mengenai pemilihan penambahbaikan penyelesaian terbaik dalam proses penambahbaikan. Peringkat pengenalan menggunakan kualiti fungsi penempatan yang diubah suai, peringkat ramalan menggunakan reka bentuk integrasi eksperimen dengan penyelakuan peristiwa diskret, dan peringkat pemilihan melibatkan beberapa kriteria membuat keputusan dengan analisis statistik. Model IPS dibina secara sistematik dengan

memasukkan alat-alat yang sesuai diperlukan dengan aspek kriteria keputusan peringkat demi peringkat untuk menambahbaikan pemilihan penyelesaian. Verifikasi dan Validasi model IPS telah dijalankan dalam jumlah enam persekitaran kajian kes yang berbeza untuk mencapai matlamat penambahbaikan proses masing-masing. Model ini berjaya mencapai hasil yang diharapkan daripada kajian kes, seperti pengurangan kos, penjimatan quantiti operator dihendaki, dan masa pengeluaran dipendekkan. Sebagai contoh, pengurangan 20% daripada masa untuk memasang peralatan dalam Kajian Kes (CS) 1, kenaikan 16% daripada kecekapan dalam talian pengeluaran CS 2; Penjimatan 40% daripada jumlah bilangan operator dalam CS 3, kenaikan 21% daripada talian pengeluaran kadar keseimbangan dalam CS 4; Pengurangan 11% daripada jumlah masa pengeluaran di CS 5 dan penjimatan kos sebanyak RM 134,400 dalam CS6. Pengesahan kajian kes sebenar membolehkan jahitan struktur proses membuat keputusan yang digunakan dalam model untuk pemilihan berkesan penambahbaikan proses dalam syarikat, yang mana bagi kawasan penambahbaikan yang berbeza dan berkaitan dengan isu-isu manusia, mesin dan kaedah. Oleh itu, model IPS membolehkan analisis komprehensif alternatif penyelesaian dengan mempertimbangkan penambahbaikan metrik prestasi berganda untuk memilih penambahbaikan penyelesaian yang terbaik.

MODEL FOR DECISION MAKING IN IMPLEMENTING PROCESS IMRPOVEMENT

ABSTRACT

Industries, especially the manufacturing industry, must respond quickly and efficiently to customer needs and to be market competitive. In response to the advanced rapid changes in the market, the industries needed to continuously refine their operational processes to reduce waste in production department. The process of selecting a solution to solve problems from a set of alternatives is critical in determining the success or failure of process improvement. Hence, an effective improvement model should be considered in introducing improvements in production through a structure solution selection process. However, prioritization and selection in focus areas and improvement measures were ignored in previous improvement models. Based on the literature study, five design requirements of model development had been found for supporting the solution selection. By fulfilling the design requirements, a new improvement model, called as Improvement Process Selection (IPS) model was developed in three stages: identification, prediction, and selection, which used to facilitate decision making regarding the selection of the best improvement solution in process improvement. The identification stage used the modified quality deployment function, the prediction stage used the integration design of experiments with discrete event simulation, and the selection stage involved multiple criteria decision making with statistical analysis. The IPS model was systematically built by incorporating those suitable tools required with aspects of stage-by-stage decision criteria to improve solution selection. The IPS model was then verified and validated in total six different

case study environments to achieve respective process improvement goals. The model successfully achieved the desired results of the case studies, such as reduced costs, increased operator utilization, fewer assigned operators, and shortened production time. For example, 20% reduction of set up time in Case study (CS) 1, 16% increment of line efficiency in CS 2; 40% saving of the total number of operators in CS 3, 21 % increment of line balance rate in CS 4; 11% reduction of the total production time in CS 5 and cost saving of RM 134,400 in CS6. Validation of the real-life case studies enabled the tailoring of the structure of the decision-making process used in the model to the effective selection of process improvement in a company, which for different improvement areas related to man, machine and method issues. Therefore, the IPS model enables the comprehensive analysis of improvement solution alternatives by considering multiple performance metrics to select the best improvement solutions.

CHAPTER 1

INTRODUCTION

1.0 OVERVIEW

This chapter presents the research background and formulates the research problem. The chapter also states the objectives of this study, the research scope, and the outline of the paper.

1.1 BACKGROUND

In modern business environments, increasing competition in the market creates an urgent need to search for ways in which manufacturing companies can differentiate themselves and enhance their competitive position. To accommodate these changes, manufacturing companies should conduct process improvement to achieve their business goals and stand out from their competitors. Performance of company should also be increased from a national perspective in term of reputation because it affects employee welfare. Manufacturing companies that adopt process improvement need to constantly evaluate their operational processes and practices (Hernandez-Matias et al., 2008). By implementing solutions on the production floor on the basis of the process improvement project, companies can achieve their improvement goals, such as proactively improving production quality, reducing manufacturing waste, and increasing customer satisfaction. Those goals attainment allows them to provide the utmost value to customers (Hales et al., 2006, Smadi, 2009).

Process improvement is carried out in the production floor not only for the processes that has been engaged with but also for the total development of the overall production floor, which consists of products, equipment and materials, and human resources. The basic concept of process improvement is that companies must regularly review their processes and resources, identify and analyze performance problems, and implement improvements systematically. The process improvement project aims to determine and analyze problems. Subsequently, a range of feasible alternatives for improvement must be identified before the final selection decision is made, and are then translated into improvement actions. The ability to generate a set of alternative solutions is an integral part of the process improvement stage, which can be considered a problem-solving and decision-making procedure. To successfully achieve process improvement objectives, the improvement solution can be any of several wide-ranging improvement programs, such as just-in-time and poka-yoke, or specific decisions, such as redesigning the steps of operational processes, providing frequent training to operators, and introducing jigs.

Process improvement is a central issue that can be resolved by detecting and eliminating production waste especially relevant to resources (Pulat, 1994). The key fundamental to embed with any process improvement is the removal of waste (Lewis and Cooke, 2013). The reduction of production wastes was defined as the fundamental thinking behind lean manufacturing and, as a result, an analysis of such wastes is needed in order to effectively reduce or eliminate it. Thus, an aid or medium is required to develop clear, systematic, and structured ways to guide industrial practitioners to go through the stages of process improvement, such as six sigma methodology (Kaushik et al., 2012, Jirasukprasert et al., 2014), Plan-Do-Check-Action (Smadi, 2009) , Ford eight disciplines problem solving (Behrens et al., 2007) and so on. This requirement has been supported by previous studies, which claim that models, methods, and frameworks based on various engineering approaches to problem solving are available (Bamford and Greatbanks, 2005, Raisinghani et al., 2005).

In process improvement, when several solutions of problems are obtained, company will face dilemma of selecting the right solution. When having more alternatives, decision-making becomes much more difficult especially in limited projects resources, small budget and long period of scheduling (Firesmith, 2004). The company should consider the best solution alternatives with limited resources. One of the keys to making the right decision is to prioritize between different alternatives (Aybüke and Claes, 2006). This fact make the prioritization for best solution needed to be performed in process improvement. In order to determine the alternative of best solution, there is a need for a model to support decision making in selection process through prioritization.

1.2 PROBLEM STATEMENTS

When new and valuable improvement opportunities are suggested, improvement often fails to meet expectations despite initial success (Anand and Kodali., 2009). In several extreme cases, the implementation of improvement solutions fails to deliver the desired results despite adherence to the implementation procedures of these solutions. One reason for such failure is the improvement team's limited understanding of the problems and their inability to systematically carry out process improvement (Chan and Choi, 1997). An unclear and non-systematic improvement model confuses teams, who then fail to meet the requirements for improving the process (Taner et al., 2007).

Therefore, evaluating potential solutions and selecting the best solutions with a structure model are imperative for the success of the improvement project.

Various tools for analysis are employed in process improvement. Some of the tools criteria are not focus on identifying dissimilarity in weighting of each decision criteria. Hence, it was difficult to order and rank the problems as well as facing dilemma in deciding the improvement solutions. For instance, fishbone diagrams qualify only the root cause but not focus on the significant or criticality level of cause (Yung, 1996). An improvement opportunity is difficult to identify and calibrate, and problems are difficult to order according to their level of significance when quantitative data are not used. Thus, the team has to make a decision based on their personal experiences. However, an inappropriate decision may result in the selection of inappropriate improvement solutions. Similarly, such inappropriate improvements eventually demoralize the personnel involved and result in the termination of the overall project.

Furthermore, when the areas considered consist of more than one problem area and improvement solution, industries cannot solve all problems at once because of limited resources. Therefore, prioritization is required to identify the proper direction of process improvement. Varghese (2004) and Siha and Saad (2008) developed process improvement models to determine the appropriate areas to be prioritized. However, solutions were not ranked and prioritized according to the need for implementation. When numerous solutions are simultaneously generated, solution selection becomes one of the greatest obstacles to the success of process improvement projects. Therefore, the selection of an improvement solution with a suitable model is of utmost importance. The incorrect selection of solutions is detrimental to company performance.

The linkage of essential decision-making aspects and criteria has been neglected in process improvement practices for identifying and selecting accurate solutions (Kim and Arnold, 1996, Boyer, 1998). One possible barrier is the improper relation of decision criteria, which results in the failure of improvement projects. Certain industries cannot link their selected solutions to the goals of their improvement projects although these goals are correctly specified initially (Jiang and Klein, 1999). Therefore, adopting suitable quantitative linkage criteria, from identifying opportunities to selecting solutions, is critical to the success of improvement projects.

The performance of a potential improvement solution cannot be accurately evaluated with only one criterion. Therefore, several improvement solutions must be ranked with many different criteria and conflicting performance measures. With multiple performance responses, the team habitually faces a dilemma, particularly in selecting the best solution from a wide range of feasible improvement solutions when no single improvement solution is best for all measured performance responses.

Chakraborty and Mishra (2014) claimed that there is little guidance available on how to actually come up with improved process. Hence, the implementation of process improvement requires a structured improvement model (Lohrmann and Reichert, 2013). Identification of the appropriate solution at the initial stage of the improvement project significantly provides a positive outcome. Otherwise, the inappropriate changes pose high risks of failure, which would result in loss of production time and therefore increase cost Therefore, as an initial effort to fill this gap and resolve the stated problems, research on this context should be conducted. In this regard, the present study develops a process improvement model.

1.3 RESEARCH OBJECTIVES

This study aims to develop a systematic way of prioritizing and selecting the best improvement solution. The outcome of this research will provide an improvement model that assists industrial practitioners in choosing the most suitable improvement solution to production problems through prioritization. In this regard, the objectives of this study are as follows:

- To develop a systematic and effective model of process improvement that focus on solution selection
- To incorporate prioritization into process improvement for selecting best solution
- To validate the developed improvement model in real manufacturing environments

1.4 SCOPE OF RESEARCH

The developed process improvement model mainly concerns the solution selection process and is substantially supported by various tools for prioritization and narrowing down the areas of improvement. Various tools can be used for supporting the decision making process to determine best solutions in improvement projects. The proposed model for the selection of improvement solutions adopts variety of main tools, such as relationship matrices that used in quality functional deployment (QFD), Taguchi methods in simulation and grey relational analysis (GRA) tools in respective stages. The scope application of developed model is focusing on improvement activities that related to man, machine and method issues. Furthermore, the developed model only applicable when more than three production problems had been found in the initial stage since the model focus on decision making for prioritization. This study provides a clear idea regarding a process improvement model for implementing improvement projects in real-world companies. To illustrate the improvement functions and effects of the developed model, six industrial case studies in Malaysia are presented. These case studies used different problems that related man, machine and method issues under different production environments, such as fabrication and assembly line. This study contributes to the development of a systematic process improvement model, which emphasizing appropriate strategies in appropriate areas for improvement.

1.5 EXPECTED RESEARCH OUTCOMES

Manufacturing companies need to keep prices and manufacturing cost low to be competitive. One way to increase profit is to reduce waste costs by adopting a designed model. This measure is especially useful for companies that often require a systematic and effective improvement method to resolve different operational process problems, which related to man, machine and method issues. Therefore, the findings of this study, which is development of process improvement model, can be used to improve and strengthen company performance. The effective improvement model is considered to permit a decision making analysis of their state for improvement.

When the company faces problems on selecting the best solutions from a wide range of suggested potential solutions either in the fabrication or assembly production continuous line, the proposed model can suitably be used to facilitate the decision making process in selection improvement solutions. Industrialists can use the developed model as a guide toward achieving their improvement targets that related to man, machine and method issues in production floor. QFD, Taguchi methods in simulation and GRA tools adopted in the model to focus on how the decision-making process can be systematically, practically, and effectively implemented. Thus, the solution selection process is going through the prioritization process in QFD, then running experiment for predicted result through Taguchi method, and end up analysis in multiple performance measures by using GRA before any concrete implementation in the shop floor. The development of the improvement model in this study emphasizes the identification of an accurate improvement solution in systematic and effective way. These initiatives enhance the competitiveness of companies and sustain their growth to respond to the rapid changes in the market.

1.6 THESIS OUTLINE

An overview of the thesis is presented as follows.

- **Chapter 1**: This chapter provides the research background, problem statement, research objectives, scope of research, expected outcomes, and thesis organization.
- **Chapter 2:** This chapter reviews the literature that related to this study. This literature includes the critical thinking, ideas, and approaches of other researchers in the process improvement area.
- **Chapter 3**: This chapter describes the research methodology, including the development of the process improvement model, the method for gathering data, the measurement method, and the techniques used in data analysis to obtain the final results.

- **Chapter 4:** Case studies are conducted to validate and verify the model. The results of the implementation are discussed in this chapter, as are the results for the initial and analyzed data. Recommendations for improvement are provided, and production operations are assessed.
- **Chapter 5:** This chapter provides an overall discussion of the developed model on the basis of various case studies. Findings and important issues are explained.
- **Chapter 6:** This final chapter presents conclusions and proposes future research. The findings are also briefly discussed.

CHAPTER 2

LITERATURE REVIEW

2.0 OVERVIEW

This chapter introduces process improvement by defining the terms “process” and “improvement.” Various levels and needs of process improvement are presented. The process improvement model, including its definition, categories, relevant issues, and tools, is explained. Previous process improvement schemes, methodologies, frameworks, roadmaps and models are classified into three categories, namely, subjective, methodological, and combinational models. Each category leads to a unique and systematic way of process improvement. Two groups of approaches: approaches to prioritization and to multiple performance evaluations, are then comprehensively discussed. Findings from the literature are discussed at the end of this chapter.

2.1 PROCESS IMPROVEMENT

The term “process” carries many definitions formulated from different views (Tinnilä, 1995). Almost every related journal has its own interpretation and perspective of this term. A process is a series of linked activities, tasks, or actions that are carried out in a specific order to accomplish the objective by transforming the input into output, which must create value to ensure customer satisfaction. It indicates the information and resources that are needed to achieve an output in the form of goods and services. In the context of business process, resources such as people, materials, energy, tools, equipment, and procedures are vital for creating valuable output and enhancing the ability of a process to transform inputs (Armistead et al., 1995).

Davenport and Short (1990) defined the process that involved in two types of activities, which were managerial processes and operational processes. Managerial processes are central to the control, planning and providing resources for operational processes. It is the process that manages the operation and function of a system. Typical managerial processes include strategic planning process, expense and capital budgeting, and cost management. Operational processes help to design, produce and deliver the product and service of company day to day. It involves in carrying out of the organization's basic business purpose daily. For example, the production process and activities of supporting production are the operational process that constitutes the core business of a manufacturing company and creates the value to customer. This study focused on operational processes type, typically activities in the production floor.

The Oxford dictionary defines "improvement" as an action that makes something better or a thing better than something else. In other words, improvement creates a condition more desirable than a previous one. Generally, "process" and "improvement" are combined and interpreted from two perspectives (Sørumgård, 1997):

1. The improvement of a process, particularly of the actions involved
2. The improvement of something by means of a process, particularly with regard to the goal of the process

In the first interpretation, the target of improvement is the process itself. The primary interest is the improvement of process quality in terms of effectiveness and efficiency. The product of the process plays an important role in this approach, but only as an indicator of process quality. One example of this approach is process redesign (Mansar and Reijers, 2007).

In the second interpretation, process is a means for accomplishing improvement. The most common target for improvement is product quality. The common factors considered in improving product quality are the defect rate and customer satisfaction. Process in this case acts as a tool for measuring product quality. One example of this approach is process re-engineering (Neill and Sohal, 1999).

These interpretations suggest that process improvement addresses not only the process itself but also the entire development scenario, including aspects are products, equipment, and materials. Linked activities transform inputs into valuable outputs through the integration of those aspects. Most approaches support the process-centered view on improvement. This view refers to improvement of the process and improvement by means of the process (Sørumgård, 1997). Although process improvement can be interpreted in different ways, its main objective is to improve the effectiveness and efficiency of operations which mostly depending on cost, time, quality, and flexibility (Pourshahid et al., 2009). However, the ways in which process improvement methods are implemented still vary.

2.2 LEVEL OF PROCESS IMPROVEMENT

The previous works had shown that the process improvement had been grouped through differentiation (Macdonald, 1995, Povey, 1998, Hanafizadeh et al., 2009). When defined from an engineering perspective, process improvement spans three distinct levels as shown in Figure 2.1 that range from incremental continuous improvement to radical re-engineering. Each level of approach has its own set of considerations and is employed under different circumstances. In addition, each approach is differentiated by the grade and type of improvement (incremental or radical), cost and application frequency, and expected improvement result.

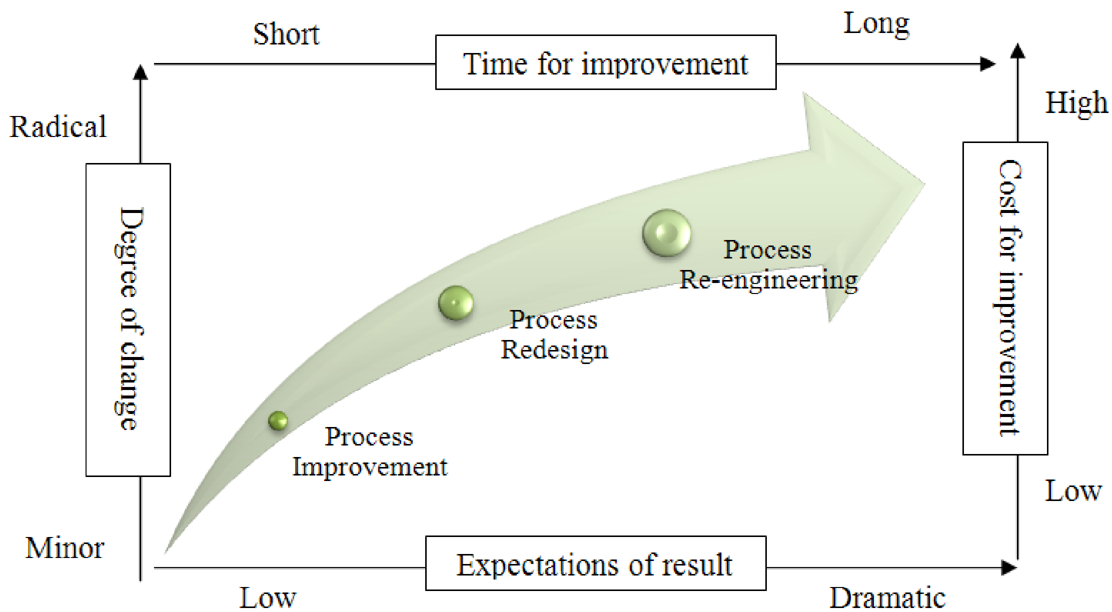

Figure 2.1 Levels of process improvement as adapted from Macdonald (1995)

Figure 2.1 indicates that process improvement is an approach toward achieving incremental performance improvements and fine-tuning. This approach, which tends to result in only minor improvements, is confined within functional boundaries. This level of changing tends to focus on streamlining and improving the existing system or activities (Berente and Lee, 2013). The focus of this level is small improvements, which are characterized by solving problems of one part of a process or its activities.

The next level of improvement is process redesign, was more radical improvement change if compared to process improvement. At this level, the focus is performing improvements not only one part of a process or its activities, but also on integral and whole processes. This level targets major business processes with cross-functional boundaries in terms of their interdependent tasks and resources. This level of changing commonly called as “business process re-design” which is more neutral than re-engineering with respect to the pace or size of the change (Mansar and Reijers, 2007). Zellner (2013) derived four general patterns of business process re-design which are combination, elimination, rearrangement and separation of activities. From his validation through laboratory experiment, those selected patterns had been facilities the redesign of business process.

Process re-engineering undertaken to achieve dramatic performance by concentrating on radical changes (Vakola and Rezgui, 2000). Also it can be represented as a new beginning, another chance for restructuring development of processes as stated by Guo and Shao (2012). Re-engineering can refer to all aspects of restructuring an organization’s processes and related inter-departmental and inter-functional issues. For example, the aspects of a re-engineering project include process activities, people’s jobs and their reward system, organization structure, and roles of process performers and managers (Valiris and Glykas, 1999). This level of changing commonly called as “business process re-engineering”, which involved all aspects of restructuring an organization’s processes and related inter-departmental and inter-functional issues (Parvin and Salvati, 2014). Lai et al. (2013) claimed that business process re-engineering requires innovations and organizational change, in order to reach superior and dramatic performance of improvements.

2.3 NEED FOR PROCESS IMPROVEMENT

Manufacturing companies should be encouraged to exert substantial effort to carry out process improvement for several reasons. Increasing market competition and the need to reduce costs for demand have led many companies to undertake process improvement activities. Madu (2000) suggested that the survival of any business depends on its ability to effectively compete in the challenging and competitive manufacturing field. Therefore, manufacturing companies need to keep abreast of global challenges and invent new technologies to stay competitive. Manufacturing companies need to jump into the process improvement bandwagon. The company gains the competitive advantages through better processes in manufacturing (Shahzad and Zdravkovic, 2009). The most common target for improvement is the supporting recourses of the process. These actions often follow a specific method to create successful results in terms of cycle time reduction and identification and elimination of the causes of low specification quality, process variation, and non-value-added activities. Process improvement methods focus on understanding and improving the processes. Effective process improvement efforts achieve desirable results, including reduced costs, increased customer retention, and improved employee satisfaction. This improvement directly improves company profitability. Companies that continuously practice process improvement survive and grow in the competitive market.

Business growth is an important driver of the assessment of process improvement. The implementation of process improvement allows a company to maximize its ability to reach its strategic goals. In this regard, companies must constantly evaluate their operational processes to compete in the modern business environment. Companies that effectively adapt to the changing environment thrive. As industries continually provide superior products or services at low cost, process improvement plays an increasingly important role in the efforts of companies to remain competitive and successful (Biazzo, 2000). A structured form of improvement is needed to support process improvement. This process improvement model is discussed in the following section.

2.4 PROCESS IMPROVEMENT MODEL

A model depicts the stages or processes through a supporting structure from initiation to conclusion and the relationship among them. The stages or processes in a model are based on the identification of a key criteria or an idea of a concept, and practical application in the related context (Smyth, 2004). The key criteria between the concept and its practical application can be linked through the development of the model (Deros et al., 2008). A visual or symbolic representation of a model facilitates the expression of key criteria in a concise and comprehensible form, such as flow charts, tree diagrams, mind maps, or shape-based diagrams, which are usually designed in a simplified form. Terms such as “frameworks,” “schemes,” and “roadmaps” overlap with the term “model” because they are interrelated and have the same purposes.

Several purposes of model development have been highlighted by different authors (Askin and Standridge, 1993, Mishra et al., 2007). Model development ensures the complete understanding of different viewpoints and adheres to key criteria to assist management in making decisions. Models provide a systematic, comprehensive, and timely way to guide users from the initial stages of a process to its full implementation. Model development therefore offers not only an overview but also detailed information on each criteria and its relationship with other criteria.

In process improvement, models serve as a guideline or methodology for solving problems in the production floor, namely process improvement model. A process improvement model can be defined as the order of activities to be fulfilled when improving a process. Aside from the improvement process, the decision-making process in a process improvement model is crucial for solving production problems. The decision-making process is a set of steps, namely problem identification, solution selection, and evaluation of a decision's effectiveness. Therefore, evaluating potential solutions and selecting the best solutions with a structure improvement model are imperative for the success of the improvement project.

Furthermore, the linkage of essential decision-making aspects and criteria has been focus in process improvement practices for identifying and selecting accurate solutions. By following the improvement model, the proper relation of decision criteria determines the success of improvement projects. Therefore, adopting suitable quantitative linkage criteria, from identifying opportunities to selecting solutions, is critical to the success of improvement projects. Besides, the success of the process improvement project also hinges on the successful adoption of suitable tools. To support the decision making process, tools are adopted to generate results and carry out the issued oriented improvement activities in a structure way. A clear and systematic improvement model with linkages of decision criteria can be used to direct the teams to meet the requirements for improving the process. Identification of the appropriate solution at the initial stage of the improvement project significantly provides a positive outcome. Therefore, as an initial effort to fill those gaps, research on this context should be conducted. In this regard, the present study develops a process improvement model structure as shown in Figure 2.2 for reviewing the existing works.

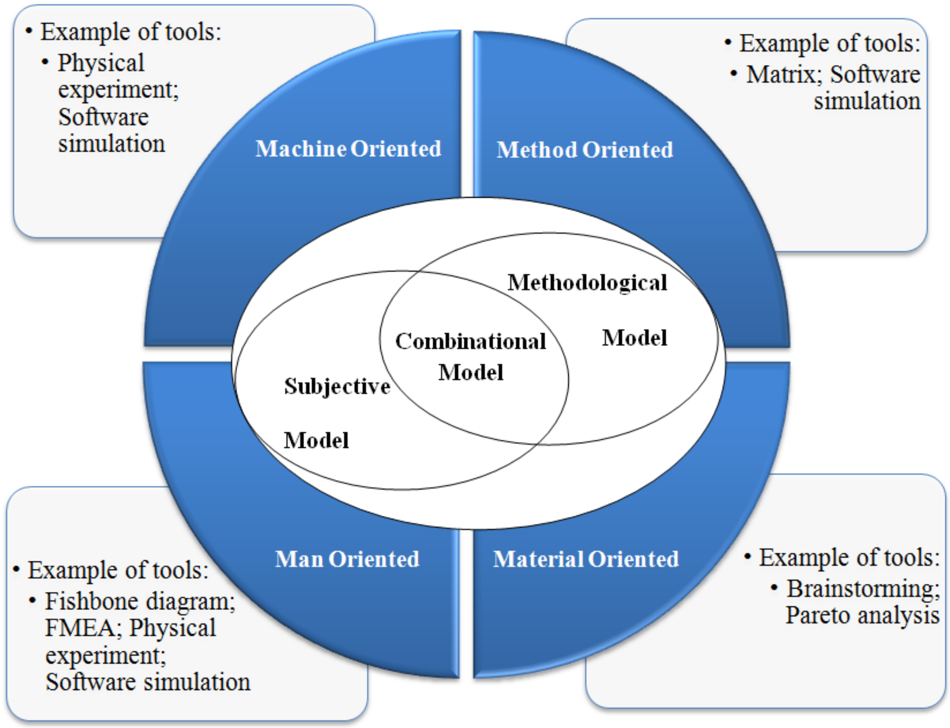

Figure 2.2 Process improvement model in terms of category, issue orientation, and related tools

Figure 2.2 illustrates the positioning of the literature study. It reviews the relevant literature which underpins this study on describing the selection process of existing works in process improvement model categorization, which are subjective, methodological, and combinational models. The categorization is mainly based on the way or method of decision making is carried out in the selection process that is further elaborated in Section 2.3.1. The existing improvement model are reviewed and categorized in the related groups according to the approach of supporting solution selection as presented in Section 3.0. Each of the categories is reviewed according to the four issues in a series of oriented improvement focal point, which are man, machine, method, and material (4Ms). A brief clarification of the 4Ms issues is presented in Section 2.3.2. In order to solve the respective issue oriented improvement focal point problems, the listed tools needed to support the teams, thus decision can be made under identifiable guidelines and positioned to overcome the obstacles of improvement selection. This will result in obtaining the best improvement solutions. Each of the related tools as shown in Figure 2 will be briefly explained in Section 2.3.3. However, the listed tools in Figure 2 are not meant to be inclusive in all the existing process improvement tools. In this study, only the related tools in solving the respective issues in the reviewed paper are included. In the literature review, the combination of these three major categories provides the theoretical background towards the development of the improvement model.

2.4.1 **Categories of process improvement model**

As mentioned previously, the process improvement model is developed to support the selection of solution in process improvement. This study focuses on the early stages of the problem-solving process and on the ways improvement models generate and select the best solutions before implementation. Over the years, various improvement models have been developed and applied to the selection of solutions to different problems with different tools. Various tools have been adopted to support users in making appropriate decisions for solution selection. Process improvement models are classified into subjective, methodological, and combinational models.

The subjective improvement model qualitatively examines ideas, thoughts, and concepts to select the best solution as shown in Figure 2.3. This model is applicable to field experts whose judgment and experience serve as its basis. It emphasizes subjective understanding, discovery, collection, judgment, and classification rather than prediction and control. Given a set of goals, the subjective improvement model employs qualitative tools to determine the best solution. These tools include fishbone analysis, force field analysis, and SWOT analysis. Companies also use subjective qualitative approaches, such as brainstorming, focus groups, interviews, and customer visits, as an aid to prioritizing improvement solutions (Bañuelas et al., 2006).

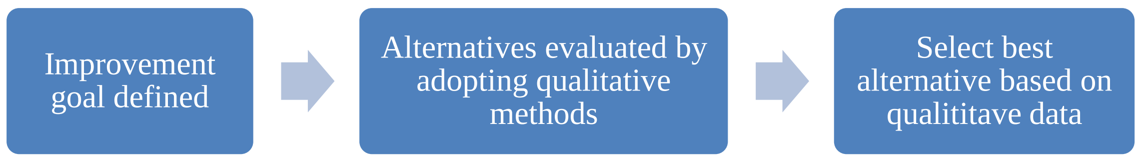

Figure 2.3 Selection process in subjective improvement model

The methodological improvement model quantitatively utilizes numerical data to select the best solutions as shown in Figure 2.4. The decisions made with this model are based on the performance data of each possible solution. All possible solutions to improve a given situation are based on goals and are evaluated via simulation. Simulations predict results before physical experiments and actual implementation without the need for much time and money (Ingemansson and Bolmsjö, 2004, Chen et al., 2011). Simulation techniques may be used as either direct improvement methods or decision support tools (Johansson and Grünberg, 2001). The solution that leads to the most desirable performance is then considered for final selection.

Figure 2.4Selection process in methodological improvement model

The combinational improvement model combines the features of the both subjective and methodological models. In this combinational model, improvement solutions are identified, prioritized, and selected qualitatively and quantitatively as shown in Figure 2.5.

Figure 2.5 Selection process in combinational improvement model

2.4.2 **Issue orientation in process improvement**

In this study, issue orientations in a process improvement model are classified into man, machine, method, and material (4M), which are the main production resources (Kwang et al., 1999, Arsovski et al., 2011). From the "man" perspective, process improvement targets issues attributable to human error, including those resulting from poor posture, poor arrangement and assignment of operators. From the "machine" perspective, process improvement targets workplace issues, including machine allocation or production floor layout, workstation design and equipment arrangement. From the "method" perspective, process improvement targets issues related to operation and manufacturing processes, including machinery parameter settings and the conditions of manufacturing processes. From the "material" perspective, process improvement targets product issues, including the product design and elimination of defects.

The pervious works in process improvement that related 4M issues will be then discussed in Section 2.5 for respective model categories. Besides that, the four issues orientation can be considered as root of manufacturing wastes that do not add value to a product or process. Hence, the seven wastes classification had addressed in this study, such as defects, re-work, transportation, waiting, inventory, movement, overproduction, and unnecessary processing (Ohno 1988).

2.4.3 Tools used in process improvement

Tools that fix these issues are essential in analyzing and selecting improvement solutions because they are vital elements of any successful improvement process. These tools support process improvement by facilitating the analysis and selection of solutions (Griesberger et al., 2011). A brief description of some related tools that had proven functional in supporting the process improvement practices is presented below.

Fishbone analysis

A fishbone diagram is a tool for classifying the potential causes of problems (Lee and Chang, 2012). This diagram helps generate ideas through team creativity and renders a visual image of the relationship between a given problem and its potential causes. Tan and Platts (2003) stated that this diagram suitable for detail analysis on specific narrow problems. Once the causes are identified, improvement scope is narrowed down and used to formulate improvement solutions. This tool is applied to improve the performances of manufacturing systems, including their performances in terms of waste reduction (Hassan, 2013) and product quality (Jirasukprasert et al., 2014). The grouping of causes with this tool is subjective to group members. Therefore the potential causes are typically based on individual's creativity, opinion and experience. Furthermore, the fishbone diagram makes all potential causes look equally plausible and equally important. It is not very good at pointing out which of the possible causes is most likely or most important.

Pareto analysis

Pareto analysis is a quality analysis tool used to understand the frequency of occurrence of various issues (Gijo and Sarkar, 2013). Pareto analysis breaks down a massive problem into small parts and identifies which ones are the most important (Stojcetovic et al., 2013). Jain (2013) and Piliouras et al. (2013) confirmed that Pareto analysis prioritizes critical issues. However, this tool considers only one element (i.e., cost or frequency) as the baseline to select where a user should focus its improvement efforts (Marriott et al., 2013). This limitation had been solved by using the multiple criteria pareto chart that developed by Grierson (2008), which considering more element than traditional Pareto charts.

Simulation method

Simulation is an imitation or representation of a selected situation or operation of a real-world process or system for experimental testing. In process improvement, simulation is used to visualize, analyze, and optimize a complex production scenario through animation prior to actual implementation (Liu et al., 2012, Raffo et al., 1999). Simulation can be classified into computational simulation and physical simulation. Computational simulation is run on a computer to predict outcomes on the basis of the simulated behavior of a real-time scenario (Tsai, 2002). This simulation in process improvement has been widely used in different areas, such as in studies of human posture and motion (Prakash et al., 2013), manufacturing operation processes (Faris et al., 2013), manufacturing systems (Eldabi et al., 2002), and product defects (Demurger et al., 2008). In an experimental study based on physical simulation, real objects are substituted with physical mock-ups smaller and cheaper than the actual object or system. Process improvement projects rarely employ physical simulation, particularly when simulating manufacturing processes (Yang and Tarng, 1998) and product quality (Kaushik et al., 2012).

Brainstorming

Brainstorming is a simple way for a group to generate multiple ideas, such as possible solutions to a known problem. In brainstorming sessions, moderators often encourage participants to prioritize the quantity of generated ideas over their quality; in this way, many ideas may be identified and then filtered to determine the most suitable ones (Peña et al., 2012). Brainstorming is used to identify and prioritize areas that require improvement in quality product (Soni et al., 2013) and manufacturing processes (Gijo and Scaria, 2013).

Matrix

A matrix diagram shows the relationship between two, three, or four groups of information. This diagram can also provide information about the relationship, such as various elements or criteria regarding the improvement process. Chen et al. (2013) used a matrix to prioritize critical problems, whereas Arsovski et al. (2013) used one to redesign a process. However, this tool is biased toward relationship ratings and thus leads to inaccurate solutions.