UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Faculty of Manufacturing Engineering

ENHANCEMENT OF LEAN MANUFACTURING IMPLEMENTATION BASED ON DECISION SUPPORT SYSTEM USING SIMULATION AND INTELLIGENT AGENT

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MOHAMAD AMRAN BIN IBRAHIM

A report submitted in fulfilment of the requirement for the degree of Master of Science in Manufacturing Engineering

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DECLARATION

I declare that this thesis entitled "Enhancement of Lean Manufacturing Implementation Based on Decision Support System Using Simulation and Intelligent Agent" is the result of my own work except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in the candidature of any other degree.

Signature :

Name : Mohamad Amran Bin Ibrahim

Date : 28/4/2017.

APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality as a partial fulfilment of Master of Science in Manufacturing Engineering (Autonomous and Intelligent Manufacturing).

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DEDICATION

Ya Allah, hanya dengan keizinan-Mu dan kekuasaan-Mu kajian ini dapat disempurnakan.

Kepada keluarga

Ibrahim bin Hamat, Azizah binti Hassan, Mohd Zukri bin Ibrahim, Haminah binti Ibrahim,

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Terima kasih atas doa yang tidak pernah putus, tidak jemu memberi nasihat. Semoga kalian semua sentiasa dalam keadaan sihat dan dirahmati oleh-NYA.

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ABSTRACT

Lean Manufacturing (LM) is a powerful means employed to improve efficacy in the manufacturing field and get rid of waste by utilising a set of tools. Different approaches have been employed to execute LM. This involves improving the knowledge of the Lean Practitioner (LP) and supporting the offline/online decision making in evaluating the existing production system. Going by the technological growth, some researchers concur that online methods enjoy more popularity in comparison to offline ones as the former can be employed without disorder and can effectually simulate the behaviour of the manufacturing system. This study has been taken up to scrutinise the existing practice of LM execution through an online approach. Many efforts have been made to improve the efficacy of LM execution; however, not all companies have succeeded in this. The author has investigated and recommended iLeTS (Intelligent Lean Tools Simulation) as a solution to bridge the existing gap and simultaneously lower the failure percentage of the LM execution through a new simulation approach. iLeTS had been formulated using the modelling software and improved through the Visual Basic application and multi agent system (MAS). MAS is deemed appropriate for supporting this production process as agents can dynamically adjust their conduct to fluctuating environments and they can determine solutions speedily through negotiations and mutual cooperation. iLeTS is an alternative approach which can aid the LP to make swift decisions by automating the production process. This combination helps improve the user friendliness and simultaneously lower the usage time. To assess the iLeTS application, two approaches are employed: face validation and usability study. The former is utilised to substantiate the multi agent system flow in iLeTS which impacts the production process; the usability study helps gauge the competence of iLeTS in tackling several randomly occurring events. An extensive array of simulation outcomes, based on actual data, is reported and scrutinised. In concluded, based on the usability study; iLeTS is appropriate for automating the production process and competent enough for being used to make quick decisions.

ABSTRAK

Pembuatan Kejat adalah satu cara yang digunakan untuk meningkatkan keberkesanan dalam bidang pembuatan dan mengurangkan pembaziran dengan menggunakan satu set alat. Pelbagai pendekatan telah digunakan untuk melaksanakan Pembuatan Kejat. Ini melibatkan meningkatkan pengetahuan pengamal Pembuatan Kejat dan menyokong keputusan yang dibuat luar talian/atas talian semasa menilai sistem pengeluaran yang sedia ada. Berdasarkan perkembangan teknologi, sesetengah penyelidik bersetuju bahawa kaedah atas talian adalah lebih popular berbanding dengan kaedah luar talian kerana kaedah pertama ini boleh digunakan tanpa gangguan dan boleh meniru dengan berkesannya tingkah laku sistem pembuatan. Kajian ini telah dijalankan untuk meneliti amalan yang sedia ada terhadap pelaksanaan Pembuatan Kejat melalui pendekatan atas talian. Pelbagai usaha telah dilakukan untuk meningkatkan keberkesanan pelaksanaan Pembuatan Kejat; walau bagaimanapun, tidak semua syarikat telah berjaya dalam hal ini. Penulis telah menyiasat dan mencadangkan (iLeTS) sebagai penyelesaian untuk merapatkan jurang yang sedia ada. Pada masa yang sama, ia dapat mengurangkan peratusan kegagalan dalam pelaksanaan Pembuatan Kejat melalui pendekatan simulasi yang baru. iLeTS telah dirumuskan dengan menggunakan perisian pemodelan dan dipertingkatkan melalui aplikasi Visual Basic dan sistem berbilang ejen (MAS). MAS dianggap sebagai sesuai untuk menyokong proses pengeluaran ini kerana ejen-ejen tersebut boleh menyeleraskan tingkah laku mereka secara dinamik mengikut persekitaran yang berubah-ubah. Mereka juga boleh menentukan pengelesaian secara pantas melalui rundingan dan kerjasama. iLeTS adalah satu alternatif yang mampu membantu pengamal Pembuatan Kejat membuat keputusan yang pantas dengan mengautomasikan proses pengeluaran, terutamanya untuk menentukan pembuatan selular yang sesuai. Gabungan ini membantu meningkatkan kemesraan pengguna dan, pada masa yang sama, mengurangkan masa penggunaan. Dua pendekatan digunakan untuk menilai aplikasi iLeTS: kesahihan wajah dan kajian kebolehgunaan. Pendekatan pertama telah digunakan untuk mengesahkan aliran sistem berbilang ejen dalam iLeTS yang memberi kesan kepada proses pengeluaran; dimana kajian kebolehgunaan membantu mengukur kecekapan iLeTS dalam menangani beberapa peristiwa yang berlaku secara rawak. Pelbagai hasil simulasi berdasarkan data sebenar telah dilaporkan dan diteliti. Kesimpulan dibuat bahawa iLeTS sesuai digunakan untuk mengautomasikan proses pengeluaran dan ia adalah cukup cekap untuk digunakan untuk digunakan dalam membuat keputusan dengan cepat.

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Aa	Autonomous Agent
BNM	Bank Negara Malaysia
C1	Collaborative Agent 1
CM	Cellular Manufacturing
DM1	Decision Management 1
DSS	Decision Support System
EML	Extensible Markup Language
GDP	Gross Domestic Product
GUI	Graphical User Interface
IA	Intelligent Agent
IAa	Main Agent
IAarena	Arena Module Agent
IAarena	Arena Module Agent
IAb	Kanban Agent
IAbC1	Kanban Calculator 1 Agent
IAbC2	Kanban Calculator 2 Agent
IAbC3	Kanban Calculator 3 Agent
IAbC4	Kanban Calculator 4 Agent
IAc	Cellular Manufacturing Agent
IAc3S	3-Station Agent
IAc4S	4-Station Agent
IAc5S	5-Station Agent
IAc6S	6-Station Agent
IAcL	L-Shape Agent
IAcS	S-Shape Agent

IAcSh	Cellular Manufacturing Shape Agent
IAcT	T-Shape Agent
IAcU	U-Shape Agent
IAcW	Cm Workers Agent
IAcW3	3 Workers Agent
IAcW4	4 Workers Agent
IAcW5	5 Workers Agent
IAcW6	6 Workers Agent
IAcWS	Cellular Manufacturing Workstations Agent
IAd	Single Minute of Exchange Die Agent
IAid	Input Data Agent
IBb	Kanban Help Agent
IBba	Continue Kanban Agent
IBbb	Advantage Kanban Agent
IBbc	Disadvantage Kanban Agent
IBc	Cellular Manufacturing Help Agent
IBca	Continue Cm Agent
IBcb	Advantage Cm Agent
IBcc	Disadvantage Cm Agent
IBd	Single Minute of Exchange Die Help Agent
IBda	Advantage Smed Agent
IBdb	Disadvantage Smed Agent
iLeTS	Intelligent Lean Tools Simulation
JIT	Just-In-Time
LeTS	Lean Tools Simulation
LM	Lean Manufacturing
LP	Lean Practitioner
MA	Machine Agent
MAM	Multi-Arena Modelling
MGUI	Multi-Graphical User Interface
OEE	Overall Efficiency Equipment

PA	Product Agent
RDF	Resource Description Framework
SMED	Single Minutes Of Exchanging Die
SWOT	Strength, Weakness, Opportunity, Threats
TPM	Total Productive Maintenance
TPS	Toyota Production System
UK	United Kingdom
UTeM	Universiti Teknikal Malaysia Melaka
VBA	Visual Basic Application
VSM	Value Stream Mapping
WA	Workers Agent

LIST OF PUBLICATION

Mohamad, E., Ito, T., Yuniawan, D., **Ibrahim M.A.**, Saptari, A., Kasim, M.S., Shibghatullah A.S., and Ali, M.A., 2014. A Proposal of Muda Indicator Agent to Estimate Lean Manufacturing Verification. *Journal of Advance Manufacturing Technology*. 8(2), pp.71-82.

Ibrahim, M.A., Mohamad, E., Arzmi, M. H., Rahman, M. A., Saptari, A., Shibghatullah, A. S., Sulaiman, M. A., and Ali, M. A., 2015. Enhancing Efficiency of Die Exchange Process through Single Minute of Exchanging Die at a Textile Manufacturing Company in Malaysia, *Journal of Applied Science*. 15 (3), pp 456-464.

Mohamad, E., **Ibrahim, M.A.**, Shibghatullah, A. S., Rahman, M. A., Salleh. R., A., Rahman A.A.A., Abdullah, S., Sulaiman, M.A., 2016. Simulation based approach for lean manufacturing tools implementation: a review. *APRN Journal of Engineering and Applied Sciences*. 11(5), pp.3400-3406

Mohamad, E., **Ibrahim, M.A.**, Shibghatullah, A. S., Rahman, M. A., Sukarman, L., Salleh. R., 2017. Improved decision making in Lean Manufacturing using Simulation Based Approach. Internation *Journal of Agile System and Management*, 10 (1), pp 34-48.

CHAPTER 1

INTRODUCTION

1.0 Introduction

Malaysia is heading towards an highly competitive, vigorous, vibrant and durable economy, which the country expects to reach by 2020 (Pemandu, 2012). The 1980s saw significant rise in the economic growth in the manufacturing quarter in a range of 8%–11.7% annually (Bank Negara Malaysia, 2014). In 2010, in service industries, the manufacturing sector had been the primary contributor to the gross domestic product (GDP) of the country, accounting for 27.6 as presented in figure 1.1 (Pemandu, 2012). The economy had evolved into a prominent producer of quality manufactured goods from being excessively dependant on commodities in the export market (Asid, 2010). This success can be attributed to the innovation done in manufacturing entities in a bid to overcome the prevailing obstacles impeding the production scheme's performance (Mohamad et al., 2008).

Ahmed Sayem et al., (2014) and Kumar and Abuthakeer (2012) highlighted that the present-day manufacturers faced issues related to rapid distribution of goods, increased productivity, and the production of high-quality products at affordable prices. Costa et al. (2013) asserted that producing a broad range of goods in small lots would be the best approach to achieving high returns. However, it should be kept in mind that any modification done to procedures associated to the productivity within the company echelon or a manufacturing unit is in tandem with the involved cost. The capacity of a business entity or a particular corporation to realise a lead over its competitors in terms of productivity determine the level of profit margins achieved (Bhat and Shetty, 2013).

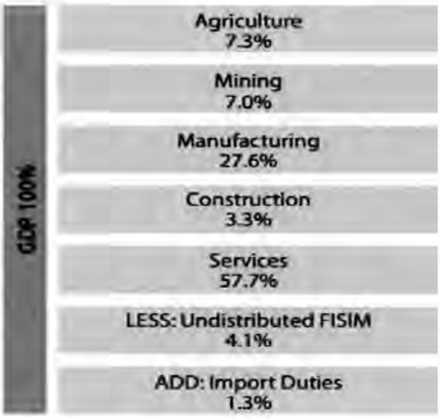

Figure 1.1: Malaysian GDP (Pemandu, 2012)

1.1 Problems statement

The dilemmas bothering the present-day manufacturers include restrictions related to space, increased production overheads, waste and elevated changeover periods. Mahfouz et al. (2011) claim that employing Lean Manufacturing (LM) would mitigate or even eliminate the problems caused by these obstacles. The principle of LM suggests that the production system can be improved by eliminating the non-value added work or waste (Ghosh, 2012). The term 'waste' here denotes the actions that would lead to depletion of resources without contributing any value to the manufactured facilities or goods (Chowdary and George, 2012). Applying LM helps reduce the processing time and ensures quick delivery of a broad range of premium goods that are favourably priced (Slack et al., 2013).

LM tools are employed not only to help identify waste in the production system but also to improve productivity (Abdulmalek and Rajgopal, 2007) by enhancing quality, reducing expenditure, cutting down lead times (Wahab et al., 2013), minimising flaws (Pettersen, 2009), and ensuring prompt product delivery (Ghosh, 2012). The use of LM opens up fourteen lean instruments. Many industries such as pharmaceutical domains (Ahmed et al., 2010), construction (Aziz and Hafez, 2013) and healthcare (Buggy and Nelson, 2005) have already applied LM in their systems.

Even though there are many companies that have adopted LM, not all have achieved complete success (Mohamad et al., 2008). According to the research of Wong et al. (2009) and Scherrer-Rathje et al. (2009), almost 40% of the companies employing LM were unsuccessful during their initial attempt. The reason for the failure may be due to incomplete preparation, lack of complete understanding of the LM philosophy, overemphasis of the LM tools (Aulakh and Gill, 2008) and poor organisation. Achanga et al. (2006), Shah and Ward (2003), Wahab et al. (2013), Kovach et al. (2011), and Hedelind and Jackson (2011) suggested that a work setting without LM culture, lack of information and comprehension of LM and poor decision making by the leaders were the major obstacles for implementing LM successfully. A survey by Kovach et al. (2011) revealed that most companies could not implement Value Stream Mapping (VSM), standardised work, and Kanban in their production line.

To mitigate these issues, authors found two methods in LM implementation, which could be employed to improve the effectiveness of decision support. Some researchers would enhance the evaluation phase to increase the effectiveness of LM implementation and some would hone the training skills to improve the workers' knowledge of the system. The current research concentrates on two parts to hone training skill: off-line and on-line. However, Kovach et al., (2011) stated that off-line is less effective because achieving success requires a person with years of experience and knowledge related to lean manufacturing. While, the on-line evaluation method has gained popularity as it can help identify the obstacle and make the right decision accordingly (Ruikar and Telsang, 2012), analyse complex production system, mimic behaviour of the operation system (Yilmaz et al., 2015) and forecast the system's future state (Mohamad et al., 2013a). Even so, simulation techniques involving the present-day LM tools are not easy to apply and can be affected by the lack of communication between the customer and the modeller. This may hamper receiving of the progression information ranging from the theoretical model to the process engineering phase (Williams and Ülgen, 2012; Durk, 2012). Another setback related to this technique is the inclination towards static simulation rather than dynamic simulation (Alzraiee et al., 2013), which suggests that the development of on-line simulation is limited to domain specialists.

1.2 Research Aim and Objectives

The main objectives of this research are as follows:

1. To examine the current practices related to decision making for employing LM.
2. To propose and design a new decision support system (DSS) to improve LM implementation
3. To evaluate the proposed DSS through usability study

1.3 Limitations of Current Research Approaches

This study concentrates on DSS in the implementation of Lean Manufacturing (LM). Many researchers have proposed several methods to effectively implement LM in the manufacturing system, which include providing additional training and practical classes in either on-line or off-line. However, complete success was not achieved with the implementation of LM. As a result, Intelligent Lean Tools Simulation (iLeTS) and Lean Tools Simulation (LeTS) platforms were proposed to improve DSS for the implementation of LM. Modelling simulation as a medium and cellular manufacturing as a LM tool were employed to develop this platform, and showcase the functionality along with realisation of the LM theory. However, authors have identified the issue to make few limitations that would ensure the proper use of a platform. The limitations include the use of a constant type of method to determine the processing time parameter. For the processing time, the time unit used was minute, a class of processing occurred within the module, which ranged from a simple delay due to resource constraints to a resource constraint process involving seize delay release and a module identifier. Also, the name cannot be changed once it is displayed in the module shape.

1.4 Dissertation Outline

This dissertation is organised into five chapters, where each chapter addresses a distinct point closely linked with carrying out of this research project. The following is a brief outline of chapters:

Chapter one: It presents a research introduction, problem statement, objectives, and the research scope.

Chapter two: It involves the research background consisting of literature reviews on related research topics, namely simulation-based approach, LM to LM implementation and agent-based approach in the application of LM.

Chapter three: This chapter highlights methodology to develop Decision Support System (DSS) using simulation to improve the implementation of LM. In general, it includes the overall flowchart on how the research is carried out step by step.